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ENHANCING AGRICULTURE IN AFRICA

A ROLE FOR U.S. DEVELOPMENT ASSISTANCE

CONGRESS OF THE UNITED STATES   OFFICE OF TECHNOLOGY ASSESSMENT

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Foreword

Few African farmers, herders, and fishers have adequate resources to assure continuous food supplies. For them, access to additional resources is vital, along with making the best use of existing capital, information, labor, equipment, etc. On the other hand, most U.S. farmers and ranchers have a larger endowment of resources, including the natural ones upon which agriculture depends ultimately. Nevertheless, increasing numbers of U.S. farmers are choosing to reduce resource use to cut input costs and increase profits. Now, broad interests worldwide seem to be converging on making the most of modest resources. This report examines the situation of African agriculturalists specifically. We anticipate, though, that many of the important lessons learned in Africa will become increasingly relevant to U.S. agriculture.

OTA's Technology Assessment Board, in June 1985, approved requests of three congressional committees and five Board members that OTA examine low-resource agriculture in Africa. OTA published its first results in a 1986 special report[1] that focused on development in the West African Sahel. OTA's first report examined the record of U.S. assistance to nine African nations, explored the lessons learned in a decade of efforts, and suggested policy alternatives to improve the effectiveness of U.S. assistance.

This second report is cast more broadly. OTA has gathered information on agricultural production throughout Sub-Saharan Africa, looked closely at specific, promising technologies such as agroforestry, small-scale irrigation, soil and water management, and the improved use of animals. As a result, it seems clear that low-resource agriculture has a sizable potential to contribute to increased African food security. Also, it is clear that low-resource agriculture must be enhanced in order to reach its full potential. This report identifies ways that U.S. development assistance can aid this process.

The committees that requested this study are: the House Select Committee on Hunger, the House Science and Technology Committee (the Subcommittee on Natural Resources, Agriculture Research, and Environment), and the House Agriculture Committee. Of OTA's 1985 Technology Assessment Board, Senators Hatch, Kennedy, and Pell and Representatives Evans and Udall requested this work. Also, the House Foreign Affairs Committee supported OTA's assessment.

The report draws on the expertise of a large number of people. We appreciate the assistance of our Advisory Panel, the authors of contractor reports, workshop participants, and additional reviewers. Also, we owe a special debt to the Africans who responded to our request for their thoughts and advice on U.S. technical assistance and development policy. Of course, OTA remains responsible for the analysis and the report does not necessarily represent the views of individuals who participated in the study.

John H Gibbons

JOHN H. GIBBONS
Director

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[1] *Continuing the Commitment: Agricultural Development in the Sahel*, OTA-F-308 (Washington, DC: U.S. Government Printing Office, August 1986).

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NOTE: OTA gratefully acknowledges the members of this advisory panel for their valuable assistance and thoughtful advice. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of it contents.

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[1] Resigned as of June 24, 1986.
[2] Appointed as of May 19, 1986.
[3] Resigned as of Apr. 24, 1986.
[4] Appointed as of Feb. 12, 1986.
[5] Appointed as of July 16, 1986.
[6] Resigned as of Sept. 26, 1986.
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[1] From March to August, 1986.
[2] Until December 1986.
[3] Until May 1987.

The work was back-breaking. Farmers in the Sahel were carrying rocks, really boulders, on their heads to block gullies and rebuild soil. Their grandparents grew cotton on this land but, after years of erosion, it was rock hard and bare. They came from the village to show us their work, proud of the wire-filled bags of rocks and the smidgins of soil beginning to accumulate around them. One farmer bowed as we met, welcoming visitors who had travelled far to see their efforts, and, maybe, giving us more respect as outside experts than we deserved. "No," one of us responded, "we should bow to you for the work you are doing here."

Notes from an OTA field visit near Ouahigouya
Burkina Faso, November 16, 1986.

Contents

Page
Foreword iii
Chapter 1. Summary and Options 3
Chapter 2. Prologue 35

Part I: Low-Resource Agriculture and Development Assistance
Chapter 3. The Status of Low-Resource Agriculture 45
Chapter 4. A Resource-Enhancing Approach to African Agriculture 77
Chapter 5. The Role of Technology in Enhancing Low-Resource Agriculture .. 99
Chapter 6. The Role of Foreign Assistance in a Resource-Enhancing Approach 123

Part II: Promising Technologies
Chapter 7. Improved Use of Soil and Water Resources 161
    Soil and Water Management 161
    Improving Soil Fertility 170
    Small-Scale Irrigation 178
Chapter 8. Improved Cropping Practices 195
    Intercropping 195
    Agroforestry 200
Chapter 9. Crop and Livestock Genetic Improvement 213
    Crop Breeding 215
    Animal Breeding 226
Chapter 10. Improved Use of Animals 237
    Mixed Crop/Livestock Systems Using Small Ruminants 243
    Animal Traction 245
    Aquaculture 248
Chapter 11. Improved Systems To Reduce Losses 257
    Integrated Pest Management 257
    Improving Animal Health 264
    Post-Harvest Technologies 273
Chapter 12. Epilogue 287

Appendix A. The Assessment's Contractor Reports 297
Appendix B. Workshop Participants 303
Appendix C. African Correspondents 305
Appendix D. External Reviewers 308
Appendix E. The U.S. Department of Agriculture's Database on Low-Resource Agriculture 310
Index 319

Chapter 1
Summary and Options

CONTENTS

Page

Why Focus on Low-Resource Agriculture? 3
The Status of Low-Resource Agriculture 3
  Problems in the Face of Mounting Pressure 9
A Resource-Enhancing Approach to African Agriculture 10
The Role of Technology 13
  A Promising Technological Framework 13
  Promising Technologies 14
The Role of Foreign Assistance 17
  Congress and a Resource-Enhancing Approach 17
  Three Categories of Assistance 18
  AID and a Resource-Enhancing Approach 20
  The Road Ahead 20
Findings and Options 21

Boxes

Box *Page*

1-1. Faces of Low-Resource Agriculture 4
1-2. African Agroecological Zones and Primary Food Commodities 6
1-3. Building on Low-Resource Agriculture 10

Tables

Table *Page*

1-1. Low-Resource Agriculture and African Staple Food Production 8
1-2. Promising Technologies and Practices by Agroecological Zone 14
1-3. Findings and Congressional Options for Enhancing Low-Resource Agriculture in Africa 22

Chapter 1
Summary and Options

WHY FOCUS ON LOW-RESOURCE AGRICULTURE?

Low-resource agriculture is a form of agriculture practiced by a diverse group of farmers, herders, and fishers that is based primarily on the use of local resources but that may make modest use of external inputs, including information and technology. It is the predominant form of agriculture in Sub-Saharan Africa, and it is the major source of food production, employment, and rural income. Although low-resource agriculture has been the basis for the region's food security[1] in the past, it can no longer meet the continent's increasing needs. Nevertheless, low-resource agriculture has the potential to be improved substantially, and technology and U.S. development assistance can contribute to these changes.

The purpose of this assessment is to examine technologies that show promise to help the heterogeneous group of Africans who practice low-resource agriculture. Also, OTA's goal is to provide Congress with a range of options which, if pursued, would help Africans increase their ability to assure, on a long-term basis, timely, reliable, and nutritionally adequate food supplies.

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[1] Food security is a critical goal in Africa. It is "access by all people at all times to enough food for an active, healthy life. Its essential elements are availability of food and ability to acquire it" (*Poverty and Hunger: Issues and Options for Food Security in Developing Countries*, Washington, DC: The World Bank, 1986). This can include dependable, long-term access to food through local production, or through the power to purchase food via local, national, regional, or international markets.

THE STATUS OF LOW-RESOURCE AGRICULTURE

Africa is larger than the United States, western Europe, and China combined, and it is a continent of varied cultures and environments. This diversity is reflected in how agriculture is practiced, so the specific nature of how people farm, herd, or fish varies greatly from place to place and there is no such thing as a "typical" African farm.

Nevertheless, some common elements can be seen in African agriculture. One consistent aspect is its prominent place in African economies. Agriculture employs about three-quarters of Sub-Saharan Africa's labor force and accounts for about one-third the region's gross domestic product. Also, about one-half of the countries in the region derive at least 40 percent of their export earnings from agricultural products. Further, despite major increases in food imports in the last two decades, the region produces a high proportion of its own food—at least 80 percent of cereals, 95 percent of meat, 75 percent of dairy products, and almost all roots and tubers.

More specific similarities in African agriculture can also be found among the large majority of African farming systems that can be termed "low-resource agriculture." Low-resource agriculture is difficult to quantify because use of modern inputs (e.g., commercial fertilizers and hybrid seeds), scale of operation, proportion of crops sold, and income vary widely (box 1-1). The majority of resource-poor farmers and herders are on the lower-to-middle end in the use of these inputs, size of holdings, and cash income, however. Some use virtually no external inputs, earn little money, and produce goods primarily for their own family's consumption. Large-scale commercial ranches and farms that rely up greater amounts of inputs are not considered "low-resource"; such operations probably contribute no more than 5 percent of Africa's food production.

Box 1-1.—Faces of Low-Resource Agriculture

Definitions sometimes do not capture the essence of the activity being defined. Perhaps the best way to understand low-resource agriculture is to imagine how a resource-poor farmer or herder actually lives.*

A Farmer: Sindima is a farmer in Malawi. She is in her late thirties and lives with her five children in an area with relatively good soils and dependable rainfall. Her husband left to find work in the city and she sees him infrequently, so she heads the household, manages the farm, and does almost all the work. She farms about 2½ hectares and is able to feed her family and produce some crops to sell. By local standards, Sindima is affluent. A development assistance program has been active in her village, so she belongs to a farmers' club and has access to the extension agent for information and credit for some fertilizer and improved seeds. With this help, she plants a fairly complicated mix of crops: hybrid and local maize, groundnuts, beans, a little tobacco, and a variety of local vegetables. She uses the hybrid maize and fertilizer on about one-half hectare, but she continues to plant local maize even though it it less productive because it tastes better and is less susceptible to insect damage in storage.

Sindima's fields require heavy labor—with preparation, planting, weeding, and harvesting all timed to keep the land in production as long as the rains last. She also has household responsibilities: caring for the children, grinding maize, gathering firewood, cooking; she even brews a little beer to sell at the market. Her children help—the older girls walk to the well twice each day to get water and help search for firewood—but she can afford to pay their school fees so she encourages them to get an education.

A Nomadic Herder: Mossa is in his forties and has always lived north of Timbukto, Mali, in the vast, dry area of West Africa known as the Sahel. Mossa's nomadic community consists of about 10 related families who move together with their livestock seeking pasture and water. Animals are the core of life for Mossa, his wife, and their seven children. Cattle, sheep, and goats provide milk, butter, cheese, and, for special occasions, meat. Their heavy tents—strong enough to withstand high winds, sand storms, and the driving rain of the wet season—are made of hides, as are their sandals and many household goods. When the family needs grain or other goods, Mossa trades what he must from the herd. Mossa learned to manage his herd from his father, and through trial and error. He has a good understanding of breeding and, while Western veterinary medicine is not generally available, he has a variety of traditional, and often effective, methods to treat his animals. To Mossa and his family the herd is more than a source of income. It is a measure of their status and security. Livestock are their "bank account," their way of saving resources for bad times in a land that has unpredictable but frequent droughts.

Life has changed dramatically for Mossa over the past few years. He has far more contact with other people, and he buys more goods and food. His access to the land is changing, too. Some of the productive lands he once grazed have deteriorated, like in the place where the government dug a deep well and too many animals stripped the land of all vegetation when they came to drink. Crop farmers have taken over other of his traditional lands. During the last drought, Mossa was unable to feed his family and, for the first time had to turn to international organizations for food aid. Mossa has not recovered from that drought, when he lost more than half of his herd. He is uncertain how he will fare if another drought strikes soon.

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*Sindima and Mossa are fictional, but these profiles are composites drawn from the lives of real African people.

SOURCES: American Friends Service Committee (AFSC), *Tin Aicha Nomad Village* (Philadelphia, PA: AFSC, 1982); Michael Horowitz, *The Sociology of Pastoralism and African Livestock Projects*, AID Program Evaluation Discussion Paper No. 6 (Washington, DC: Bureau for Program and Policy Coordination, AID, May 1979): George Scharffenburger, Consultant, Washington, DC, personal communication, 1987; Anita Spring, Associate Dean, College of Liberal Arts, University of Florida, Gainesville, personal communication, 1987; and "Profiles of Men and Women Smallholder Farmers in the Lilongwe Rural Development Project, Malawri," report to Office of Women in Development, U.S. Agency for International Development, Washington, DC, March 1984.

Although the agricultural systems that comprise low-resource agriculture are typically complex, diverse, and changing, they generally share these characteristics:

- they strive to minimize risk, even if this means they obtain less than maximum yields;
- they depend on local knowledge;
- they depend on biological processes and renewable resources;
- they involve low cash costs but often require relatively high amounts of labor; and
- they are adapted to local cultures and environments, although social and ecological systems are showing increasing strains under growing pressures.

Agroecological factors, e.g., rainfall patterns, soil types, and animal diseases, also help define low-resource agriculture (box 1-2). Different crops and types of livestock have different relative importance in the Arid and Semi-Arid Tropics, the Subhumid Tropical Uplands, the Humid Lowlands, and the Tropical and Subtropical Highlands. For example, millet and sorghum are the predominant crops in arid and semi-arid regions, largely because of their greater drought tolerance. Maize is grown more commonly in areas with increased rainfall. Roots, tubers, and plantains are the major source of calories in the Humid Lowlands. Similarly, cattle are the dominant livestock in arid and semi-arid, sub-humid, and highland regions, whereas small ruminants—sheep and goats—dominate in humid lowlands because of their greater tolerance to trypanosomiasis.

Notwithstanding these general crop and livestock production patterns, descriptions based on a single commodity create an inaccurate picture of low-resource agriculture. African farming systems tend to be highly diversified, producing a wide array of crops and several types of livestock. Diversified agricultural systems help provide food throughout the year, reduce the risk of crop failure, and modulate peak labor demands.

Low-resource agriculture can be further described by the importance of non-farm activities such as soap-making, crafts, and non-farm wage employment. An estimated 25 to 40 percent of all household labor is devoted to non-farm income producing activities. Farm and non-farm tasks are commonly divided by gender and age, with certain tasks allocated to children and the elderly. Women are the major food producers in most African countries and account for almost half of the agricultural labor force that produces food and non-food crops.

In general, then, low-resource agriculture meets multiple needs for families and requires balancing scarce endowments of land, labor, capital, and other resources. This calls for complex decisionmaking and facing difficult tradeoffs. A greater appreciation exists now of the efficiency and skill of resource-poor farmers and herders, although their agricultural systems were once perceived to be inefficient and haphazard.

In a broader picture, low-resource agriculture is the predominant type of agriculture practiced throughout Africa and it makes a crucial contribution to food security—both the availability of food and the ability to buy it. It is the source of most of Africa's food, a primary income and employment source for the majority of Africans, a source of foreign exchange, and a means used to buffer against food shortfalls and famine by many of Africa's people most vulnerable to poverty.

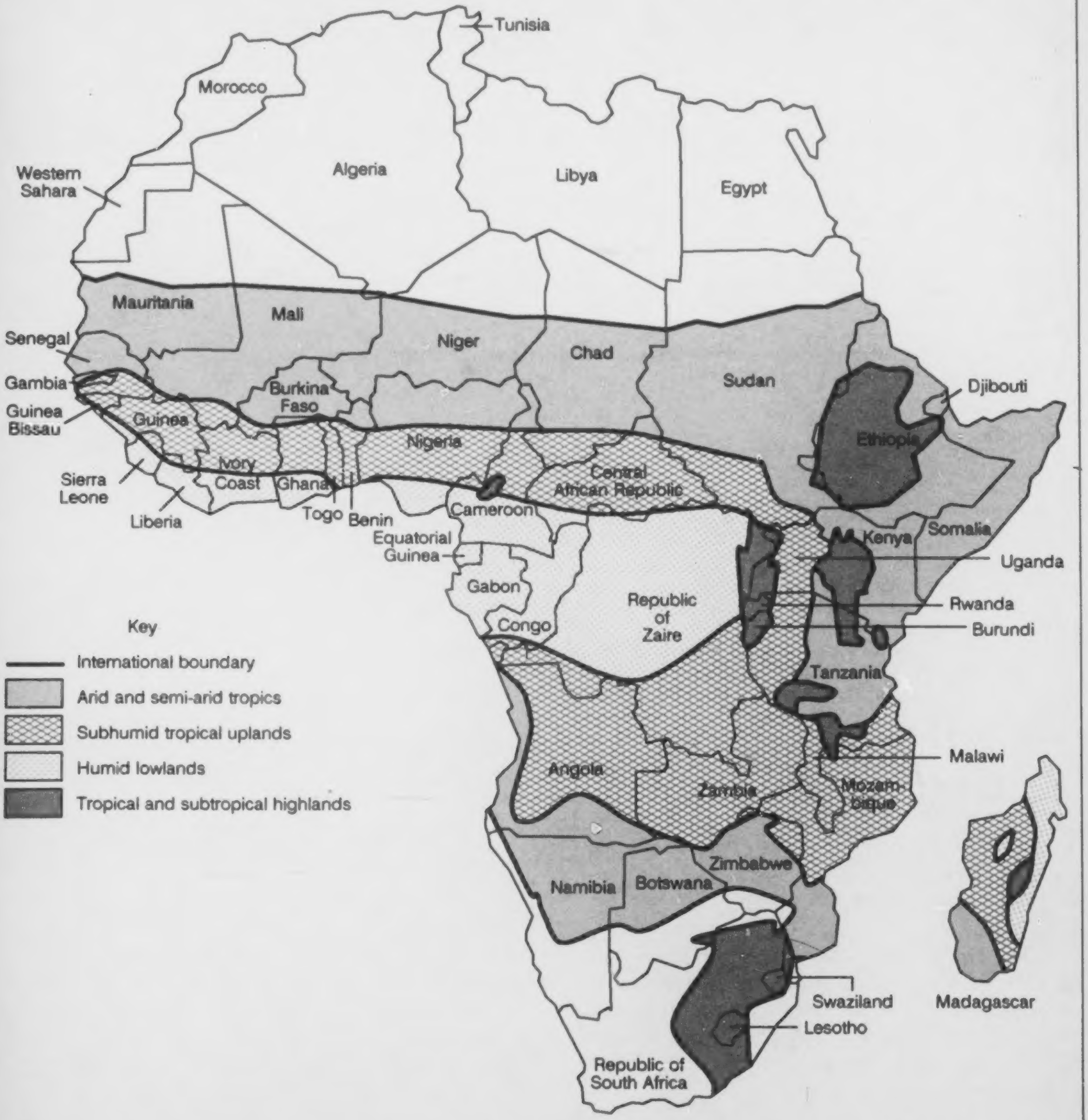
Low-resource agriculture produces the majority of grain; almost all root, tuber, and plaintain crops; and the majority of food legumes (table 1-1). In addition, a great variety of secondary crops, such as fruits and vegetables, are grown under low-resource conditions to supplement these staples. An estimated 74 percent of all livestock are raised on farms where crop production is the primary source of subsistence and livestock are an important source of cash income. And approximately 20 percent of livestock production occurs in pastoral systems, which are low-resource by nature. Fish is a primary source of animal protein for much of Africa. An estimated 85 to 95 percent of African fish harvest is from small-scale operations that do not use expensive equipment or inputs.

Box 1-2.—African Agroecological Zones and Primary Food Commodities

Agroecological zone	Length of growing period[a] (days)	Annual rainfall	Primary food commodities
Arid and Semi-Arid Tropics	1-74 (arid) 75-180 (semi-arid)	100-1,000 mm	Little cultivation in arid areas. Millet and sorghum predominant, with millet grown in drier areas. Maize in wetter areas and rice in river basins. Food legumes (e.g., cowpeas and groundnuts) important and some roots and tubers grown in wetter areas. Approximately 60% of Africa's ruminant livestock (goats, sheep, cattle, and camels) raised here by both nomadic and settled pastoralists.
Subhumid Tropical Uplands	180-270	900-1,500 mm Bimodal rainfall in East Africa	Sorghum and maize are the most important cereals, with sorghum preferred in drier areas. Roots, tubers, and plantains are important. Food legumes and rice also produced. Two-thirds of the zone are affected by trypanosomiasis (spread by the tsetse fly) which inhibits livestock production. N'Dama and Zebu cattle are the economically most important livestock followed by goats and sheep.
Humid Lowlands	270+	1,500+ mm Bimodal rainfall	Roots, tubers, and plantains predominate (e.g., cassava, yams, etc.) Some maize, rice, and sorghum. Trypanosomiasis exists throughout the zone precluding almost all but the small trypano-tolerant N'Dama cattle and tolerant goats and sheep. Some poultry and swine production.
Tropical and Subtropical Highlands	Variable	Variable	Mixed farming (livestock and crops raised on same farm) prevails. Predominant cereals are maize and sorghum. Roots and tubers (especially sweet potatoes) are important in specific countries. Plantains and food legumes are also grown. The absence of trypanosomiasis and availability of good fodder allow a stocking density four times the average.

[a] Length of growing period is the period when both moisture and temperature permit crop growth.

SOURCES: U.S. Agency for International Development, Bureau for Africa, *Plan for Supporting Natural Resources Management in Sub-Saharan Africa*, (Washington, DC: USAID, February 1986). Food and Agriculture Organization of the United Nations, *African Agriculture: The Next 25 Years: Atlas of African Africulture* (Rome, FAO: 1986). International Livestock Center for Africa, *ILCA Annual Report 1983* (Addis Ababa, Ethiopia: ILCA, 1984).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Tanzania
Malawi
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Zambia
Mozambique
Zimbabwe
Namibia
Botswana
Swaziland
Lesotho
Madagascar
Republic of South Africa
Key
International boundary
Arid and semi-arid tropics
Subhumid tropical uplands
Humid lowlands
Tropical and subtropical highlands

SOURCES: Adapted from U.S. Agency for International Development, *Plan for Supporting Natural Resources Management in Sub-Saharan Africa*, (Washington, D.C.: USAID, February 1987). Zonation for Madagascar from U.N. Food and Agriculture Organization (FAO), *African Agriculture: The Next 25 Years – Atlas of African Agriculture* (Rome: FAO, 1986); International Livestock Center for Africa (ILCA), *ILCA Annual Report 1983* (Addis Ababa, Ethiopia: ILCA, 1983).

Table 1-1.—Low-Resource Agriculture and African Staple Food Production[a]

Crop/livestock/fish	External input use[b]	Minimum estimate of low-resource production[c]
Millet	Virtually no use of fertilizers and very little use of improved seed.	72%
Sorghum	Basically the same situation as millet, but hybrids and commercial inputs are becoming more important in some areas.	61%
Maize	At least 75 percent produced without hybrid seeds and with less than recommended fertilizer levels but probably as much as two-thirds produced with non-hybrid improved seed and moderate levels of fertilizer.	37%
Rice	At least 75 percent produced using less than recommended levels of fertilizer and receiving inadequate irrigation (and no more than 5 percent using High-Yielding Varieties).	76%
Food legumes (e.g., cowpeas, pigeon peas, beans, and groundnuts)	Most crops of this diverse group receive virtually no commercial inputs, but some production is under higher resource conditions (e.g., up to 50 percent of of groundnut production).	55% groundnuts 49% beans
Roots, tubers, and plaintain (e.g., cassava, yam, cocoyam, and sweet potato)	Virtually no use of fertilizers or improved seed. Some high-resource banana production for export.	93% cassava 100% yams 100% cocoyam
Cattle	Six percent produced on ranches, generally considered high-resource; 20 percent produced by pastoralists, virtually all under low-resource conditions except for occasional veterinary care; 74 percent produced in mixed farms, a minority of this under higher resource condition, such as dairy farming in some highland areas.	
Small ruminants and other livestock (e.g., sheep, goats, poultry, and swine)	Almost all sheep, goats, and camels raised under low-resource conditions; most swine and poultry produced under low-resource conditions, but increasingly more produced under higher resource conditions, especially near some urban areas.	
Fish	As much as 85 to 95 percent caught in small-scale artisanal fisheries mostly under low-resource conditions, though increasingly fishers are using outboard motors; the remainder is harvested by large-scale offshore operations mainly by foreign-owned vessels	

[a] Aggregate agricultural data for Africa usually do not detail levels of external input use but only whether or not such inputs are used. This table shows the importance of low-resource production in two ways: first, it describes the type of input use for the production of specific commodities and second, it sets a minimum boundary on the volume of low-resource production of specific crops, based on estimates of "low-input agriculture" production in eight African countries.

[b] Column 2 provides descriptions of the types and levels of external inputs used for specific products. These descriptions help to locate where the majority of production takes place along the range of modern input use. The descriptions were compiled from a set of technology papers written for OTA (app. A) and from additional outside publications.

[c] Column 3 represents an effort to establish quantitative estimates of the minimum contribution of low-resource agriculture. The data show production under conditions of no modern input use for eight sample countries. These eight countries account for at least 50 percent of African production of maize, sorghum, millet, cocoyam, and no less than 30 percent of cassava, groundnut, and rice production. The data were compiled by the Economic Research Service of the U.S. Department of Agriculture for OTA (see app. E).

SOURCE: Office of Technology Assessment, 1988.

A large majority of the estimated three-quarters of Africa's labor force in agriculture is resource-poor. The sale of food and other agricultural products typically accounts for some 60 to 80 percent of the income of rural African producers.

Also, low-resource agriculture makes important contributions to national food security by providing a part of export earnings. A sizable part, perhaps the majority, of export crops are produced by small farmers who simultaneously raise food crops for local use under low-resource conditions. National export earnings are likely to drop when such farmers cannot purchase food reliably and, as a consequence, devote more of their own production to food crops and less to export crops.

Resource-poor agriculturalists commonly face periods of inadequate food availability either during seasonal shortfalls or more irregular famines. Many agricultural practices, such as diversification to decrease the risk of total crop failure, cassava production, bush collection of wild foods, as well as social means to share food, buffer against these periods of hunger. For example, cassava is known as a "poor person's crop": it is a highly productive staple that grows in low-fertility soils, requires little labor, and can be stored in the ground until hard times come between harvests.

Problems in the Face of Mounting Pressure

African agriculture has continuously and, for the most part, effectively adapted to meet changing conditions. But never before has it had to respond to the level of pressures it currently faces. Paramount is the pressure created by rapidly growing populations and the consequent demands on the land. The African continent has the most rapidly growing population in the world: 2.9 percent per year in 1988. Even if this rate slows slightly as expected, the continent will have triple its current population to feed within just 40 years.

Resulting intensified land use is evident in most regions in reduced fallow periods and, in some areas, falling yields and natural resource degradation. Fallow periods have dropped from 12 years to 2 years or less in Burkina Faso and from 20 years to 5 years in Angola. The shorter fallow periods can reduce yields by as much as 25 to 75 percent, and can increase weeds, soil acidity, and erosion. Many experts anticipate further yield decreases due to land degradation, continued deforestation, especially along the West African coast, and greater fuelwood scarcity.

Per capita food production and income, as well as nutritional levels, are dropping in most areas. From the late 1960s to the late 1970s, Africa changed from a net exporter of staple foods to a net importer. In 1986, the value of exports in 22 countries was not sufficient to pay for imports. Not only is the overall trend to decreasing incomes, it is also one of increasing disparity of income between rich and poor farmers and herders.

Under normal circumstances, low-resource agriculture provides most countries in Sub-Saharan Africa with adequate nourishment. At the same time, its ability to meet African's food needs is declining. This is the only region of the world where the average energy in people's daily diet decreased in the past decade. Although malnutrition generally is not perceived as a pervasive problem except during famine, a significant level of chronic malnutrition exists and as many as 90 percent of the malnourished people are resource-poor agriculturalists.

No doubt low-resource agriculture can do better, but a number of biophysical and socioeconomic constraints exist that retard progress. Generally, African soils are low in fertility and rainfall is unpredictable in many areas and low throughout much of the continent. Consequently, only 16 percent of the total land area is without serious biophysical limitations to agriculture. Also, competition for land between farmers and pastoralists; limitations of labor and capital to invest in agricultural improvements; and infrastructural weaknesses make it difficult to take advantage of new technologies and other improvements. In addition, many national policies have been unsupportive of low-resource agriculture, including the lack of investment in agricultural development and research and development policies that have not addressed the needs of resource-poor farmers and herders.

Lack of investment in agricultural research is among the serious constraints to agricultural intensification. Research expenditures by national governments decreased $80 million between 1980 and 1984, from $465 million to $385 million. Research priorities and methods often do not reflect African realities, for example, women do not receive extension services in proportion to their agricultural contributions, and crops such as cassava are researched less than their prominence in poor people's lives would justify. Many research organizations are plagued by lack of operating funds, low quality facilities, high staff turnover, and few incentives to work with poor farmers and herders.

A RESOURCE-ENHANCING APPROACH TO AFRICAN AGRICULTURE

Despite its constraints, low-resource agriculture is the major food producer and the major employer in most African countries. It is impractical to abandon traditional systems when so many people stand to be adversely affected and when the systems have an untapped potential to be enhanced. This optimism is based on: the central role this type of agriculture already plays, the vast number of people already involved, the economic efficiency apparent on the small-farm sector in Africa, and the significant capacity seen for technical improvements in current agricultural systems. In addition, if low-resource agriculture is ignored it is likely that food security will decrease, bringing unknown social impacts, and environmental degradation will continue, perhaps irreversibly. No viable alternative to low-resource agriculture exists in much of Africa today.

Low-resource agriculture can be enhanced using an approach that builds on the best of existing African agriculture while taking advantage of external inputs, information, and improved techniques (see box 1-3). This, however, presents a great challenge for development assistance—how to pursue an approach that builds on the potential strengths of low-resource agriculture while alleviating the constraints.

From its analysis of low-resource agriculture and how it is practiced in Africa, OTA found four fundamental concepts that provide insight into why low-resource agriculture has been successful in the past and how these potentials might be enhanced in the future. Using these concepts as crucial starting points, OTA developed guidelines that could be used to redirect development assistance to improve its effectiveness:

Concept 1: Most African agricultural systems, although once sustainable, are no longer keeping pace with the increased demands being placed on them. Thus, development assistance should be designed to:

- place a high priority on environmental, economic, social, and institutional sustainability;
- acknowledge the importance of sound natural resource management as a basis for improved and stable agricultural production;
- acknowledge that resource-poor agriculturalists are the primary custodians of their environment and, therefore, ensure that they benefit from development assis-

Box 1-3.—Building on Low-Resource Agriculture

In the 19th century, in the Zinder region of Niger, there was a kind of tree so valuable that the sultan decreed that people found cutting it would lose their heads. Later, in Senegal, the same trees were carefully nurtured as part of a balanced system of crops and livestock. The tree helped maintain continuous cropping of millet in the Sudan for 15 to 20 years in areas where the norm was 3 to 5 years. In each case, the species involved was *Acacia albida*—a fast-growing, leguminous tree native to Africa. It is a species that today is receiving renewed attention from the development assistance community as a way to benefit people and the land.

First, *Acacia* trees are legumes and so fix nitrogen from the air, thus, enriching the soil and improving crop yields. Another advantage is that at the onset of the rainy season the species drops its leaves, providing a leaf mulch that further enriches the topsoil. During this wet season, which is when sorghum and millet are produced, the defoliated canopy permits enough light to penetrate for cereal growth, yet provides enough shading to reduce the effects of the intense heat. During the dry season, the *Acacia's* long taproot draws nutrients from beyond the reach of other plants and stores these in its fruits and leaves. The leaves drop to the ground with the onset of the next rainy season, providing a highly nutritious forage for livestock. The livestock dung, as an added benefit, helps enrich the soil even further. Each of these benefits is important in places where few alternatives exist for improving soil fertility and crop yields.

tance to manage natural resources better; and

- focus on enhancing the capability of Africans to assume primary responsibility for their development as the surest route to sustainability.

Concept 2: Africa's heterogeneous mixture of resource-poor farmers, herders, and fishers have responded to a high degree of uncertainty and vulnerability with diverse and flexible strategies. Often these strategies minimize risk while seeking optimum stable yields, commonly at the expense of maximum yields. Thus, development assistance should be designed to:

- accommodate the diverse and flexible approaches typical of resource-poor agriculturalists: this would include enhancing their ability to manage risk, retaining their flexible household organizations, encouraging diversification of income-generating activities, and supporting indigenous experimentation and innovation in the agricultural system;
- design, implement, monitor, and evaluate policies, economic strategies, and technologies for their differing effects on people of different ages, genders, ethnic groups, and economic status; and
- have available a variety of interventions (policies, programs, projects, and institutions) so that the ones most appropriate to the varied and changing needs of resource-poor agriculturalists can be selected. Long-term monitoring and feedback should be used to adjust development activities so they remain useful and relevant as people's needs and conditions change.

Concept 3: Local resources—such as local people's skills, knowledge, practices, and institutions, plus indigenous plants and animals—reflect adaptations to the diverse local conditions found in Sub-Saharan Africa. Thus, development assistance should be designed to:

- make local participation an integral part of the initiation, design, implementation, monitoring, and evaluation of development assistance projects;
- ensure that African women, who in the past have not received the share of development assistance that their role in agriculture warrants, become full participants in the development process;
- make increased use of local organizations, including assistance to improve existing organizations; and
- build on local resources, such as indigenous plants and animals and people's knowledge of how to use them. These resources have been largely untapped by development assistance agencies and they often can be improved.

Concept 4: Low-resource agriculture in Africa is based on farming systems that have interacting ecological, social, and economic components, and these farming systems are linked, in turn, to other, larger systems beyond the farm. Thus, development assistance should be designed to:

- account for the integrated nature of low-resource agriculture and how these interrelationships affect the success or failure of interventions; and
- improve the links between farms and external systems such as markets, extension systems, and transportation networks.

The guidelines above reflect the need for development assistance to be long-term, dynamic, flexible, and to incorporate a mixture of approaches. They build on the strengths inherent in African agriculture, and are meant to direct development assistance so it supports the ongoing evolution of how low-resource agriculture is practiced. This resource-enhancing approach alone will not be sufficient for agricultural development in Africa, but it could be carried out in conjunction with other development assistance approaches such as increasing non-farm employment and improving rural people's health and education.

The resource-enhancing approach described here shares some common elements with other agricultural development strategies promoted by donors, but some significant differences also exist. For instance, many development strategies seek to improve agriculture as the primary mechanism to further overall national economic development. And within this agricultural sector, a number of approaches focus on small-scale farmers and not commercial or state-run farms. The approaches differ, however, on how best to implement this agricultural assistance.

A resource-enhancing approach seeks growth with equity—one hallmark of the New Directions/basic human needs approach to U.S. development assistance in the 1970s. Also, it draws upon approaches that were developed to respond to significant faults in the New Directions approach. The need for appropriate policy changes to spur national economic growth is drawn from the Policy Reform approach of the 1980s: the need to establish appropriate trade policy and exchange rates, to increase the efficiency of the public sector, and to develop supportive agricultural policies. Also, agriculture has specific technical and institutional needs that can be met by strengthening Africans' capabilities, as elaborated by the International Food Policy Research Institute (IFPRI).

Also, OTA finds that enhancing low-resource agriculture requires that significant attention be paid to the specific needs of resource-poor farmer, herders, and fishers. That is, policy reform must:

- assess the effects of policy changes on the poor and include measures to protect them from adverse effects;
- build African capacity to implement needed policy changes; and
- explore links between micro-level activities and macro-level reform.

Current implementation of the Policy Reform approach does not emphasize these factors.

More technically oriented approaches, such as IFPRI's, that aim to aid resource-poor farmers and herders also need to focus on specific needs:

- choosing technology for its suitability to low-resource conditions;
- giving high priority to areas where natural resource degradation is serious;
- linking research to identified needs; and
- providing farmers and herders with a broader role in agricultural development.

A resource-enhancing approach would emphasize these areas more than current technical approaches do.

These approaches are ones primarily developed by donors, with varying degrees of input from individual Africans and African governments. While donors have the responsibility to tailor work to their own goals, the lack of African involvement in determining development strategies has been a weakness of most foreign assistance. OTA surveyed some 40 African researchers and policymakers for their specific evaluation of OTA's approach for enhancing low-resource agriculture and to gather their suggestions about ways to improve the effectiveness of U.S. development assistance. These experts stessed the diversity of African agriculture—how problems and thus solutions can vary significantly from country to country. As a result, no single approach should be used to the exclusion of others. Most found OTA's analysis generally consistent with their perceptions of agricultural needs, but they did not want it to be the sole strategy of U.S. development assistance. Nor should it be perceived to maintain subsistence agriculture instead of contributing to its transformation.

Africans also emphasized the importance of increasing African capacity to deal with problems, whether by supporting education and training, institutional development (especially research), or local organizations. The starting point, many believe, is working with the technology and resources available to the majority of the people. They also expressed their hope that assistance would have a long-term focus, be free of undue political motivations, and have development as its goal. Is this possible? Some doubt that U.S. development assistance, because much of it focuses on top-down approaches and on providing food aid, can support a resource-enhancing approach without major changes in U.S. philosophy and implementation.

THE ROLE OF TECHNOLOGY

African agriculture faces a major challenge in the next few decades—it will need to double production to keep pace with a growing population and provide an adequate source of household income to purchase additional food. Although traditional, extensive, shifting agriculture will remain important in a few regions, the vast majority of the continent's agriculturalists will have to move toward a more intensified, permanent agriculture where more inputs (including information and management) are used. Technology has always played an important role in this process throughout the world. Therefore, technological innovation to enhance low-resource agricultural systems will be a major factor in determining Africa's ability to meet the challenges ahead.

A Promising Technological Framework

The technological framework with the most promise for promoting food security in Africa calls for an evolution of existing agricultural systems. More rapid improvements are possible in high-potential areas, but these areas are in a minority and changes there will not address the needs of the majority of farmers and herders who have few resources. Thus, few areas can expect rapid and widespread technological change like that which occurred in Asia. African soils are generally poorer, water and labor are often less available, human and institutional resources are less well-developed, and a number of major crops have been little researched.

To be successful given the great diversity present in African farming systems, an equally diverse array of technologies adapted to local social, economic, and environmental conditions is needed. Although Africa will benefit from global agricultural research, African problems will require a greater emphasis on Africa-specific solutions. Three efforts could contribute to this process: increasing African research capacity through human and institutional development; improving links among researchers, extension agents, farmers and herders; and giving greater emphasis to on-farm adaptive research with a farming systems perspective.

Technologies developed to support low-resource agriculture should reflect the high premium this approach places on risk aversion and the need to maintain flexibility in the face of uncertainty and limited access to resources. Farmers throughout the world are justifiably conservative when failure of technology could mean bankruptcy or even starvation. Therefore, many practices of low-resource agriculture ensure at least some production in bad periods, even at the expense of higher yields under more favorable conditions. To date, most agricultural research has emphasized maximum production

Photo credit: Consortium for International Crop Protection

Technology plays an important role in intensifying agricultural production. Crop breeding for millet and other African crops is likely to be one of the best investments in enhancing low-resource agriculture.

even though other concerns face poor farmers, herders, and fishers. For example, intercropping, a practice in which crops are grown together in an intermixed fashion helps to reduce risk of one crop's failure. Yet, only 20 percent of International Agricultural Research Center funding involves intercropping, although some 80 percent of African food is grown as intercrops.

Technological flexibility is also needed because agricultural conditions will continue to change, and at different rates, throughout Africa. Development of technology needs to build in the flexibility to react to anticipated and unanticipated events. Rapidly growing populations, migration of young men to urban areas, and the growing number of female-headed households all have implications for the development and dissemination of technology.

Currently, resource-poor farmers, herders, and fishers rely primarily on resources internal to the farm or their immediate environment. These include sunlight, rain, nutrients from plant and animal wastes, and local labor. Eventually additional external resources (purchased fertilizers, machinery, etc.) will be available but this shift to increased use of external resources is likely to be slow and gradual in many areas. Consequently, technologies that rely on local resources, labor, and institutions should be emphasized over the near term. Much development assistance has bypassed the majority of African farmers and herders because it emphasized external resource use instead. Thorough economic analysis is needed to determine the feasibility of all technological interventions, but especially to make sound choices between using external and internal inputs.

Farmers and herders' knowledge is among the internal resources available for developing useful, acceptable, and affordable technology. Their participation in identifying problems and solutions would enhance the effectiveness of technical assistance. Existing agricultural practices could be the starting point of a process combining the best of traditional and modern technologies. This requires, for example, that farmers and herders be part of research teams, that their nonformal experiments be incorporated into research plans, and that units of measure be meaningful to them.

Promising Technologies

Much uncertainty surrounds the issue of whether the technology exists to fit within such a framework and whether it can transform low-resource agriculture. It is clear, though, that some technologies and practices do exist that show high potential for wider application in the farming and herding systems of Africa (table 1-2). These promising technologies have often been overlooked and underused by development assistance agencies even though some have been developed with the agencies' support.

Table 1-2.—Promising Technologies and Practices by Agroecological Zone[a]

Technology and practices	Zone[b]	Primary benefits
Improved use of soil and water resources		
Soil and water management		
Recession farming	A,S,H	Labor-efficient method of growing crops using water from annual floods; expands area under cultivation
Water harvesting microcatchments	A,S	Increase water available from rainfall
Planting and building bunds on the contour	A,S,H,T	Increase water available from rainfall; reduce soil erosion
Tied ridges	A,S	Increase water available from rainfall
Drainage practices	H,T	Enable production on land that would otherwise be waterlogged
Terracing	T	Reduces water and soil runoff; enables cultivation on steep slopes
Minimum tillage, mulching and other soil-conserving vegetation practices	S,H,T	Prepare land without incurring costs of plowing (soil erosion, excessive leaching and compaction); organic residues and mulch help maintain fertility, reduce water and soil runoff

Table 1-2.—Promising Technologies and Practices by Agroecological Zone[a]—Continued

Technology and practices	Zone[b]	Primary benefits
Improving soil fertility		
Biological nitrogen fixation	A,S,H,T	Increases nitrogen availability
Vesicular-arbuscular mycorrhizae	A,S,H,T	Increase phosphorus availability
Manuring	S,H,T	Increases soil organic matter and soil fertility
Phosphate rock	A,S,H,T	Increases phosphorus availability
Commercial fertilizers	A,S,H,T	Increase soil fertility
Small-scale irrigation		
Gravity diversion: channeled systems	A,T	Increase water availability
Gravity diversion: poldered systems	A,S,H	Increase water availability
Mechanically fed: water lifting	A,S	Increases water availability
Mechanically fed: water pumping	A,S,H,T	Increases water availability
Improved cropping practices		
Intercropping	A,S,H,T	Reduces risk of crop failure; increases seasonal availability of food; reduces pest and disease problems; improves efficiency of resource use
Home gardens	A,S,H,T	Increase seasonal availability of food; improves nutrition in the diet
Agroforestry		
Dispersed field tree intercropping	A,S	Increases soil organic matter; provides source of fodder, fuelwood, poles
Alley cropping	S,H,T	Increases soil organic matter; provides source of fodder, fuelwood, poles
Windbreaks	A,S,H,T	Decrease wind damage, especially to seedlings; decrease evapotranspiration; provide source of fodder, fuelwood, poles
Live fencing and other linear planting	A,S,H,T	Provides source of fodder, fuelwood, poles, fencing
Genetic improvements		
Crop breeding	A,S,H,T	Provides resistance to diseases and pests; tolerance to environmental stress; improves yield
Animal breeding	A,S,H,T	Provides resistance to diseases and pests; tolerance to environmental stress; improves yield
Improved use of animals		
Mixed crop/livestock systems using small ruminants	A,S,H,T	Increase income; improve diet; reduce risk through diversification
Animal traction	A,S,H,T	Reduces drudgery; improves labor productivity; extends area of cultivation
Aquaculture	A,S,H,T	Provides source of protein; recycled nutrients; source of income
Improved systems to reduce pest-loss		
Integrated pest management		
Quarantines	A,S,H,T	Reduce risk of accidental introduction of pests
Host resistance	A,S,H,T	Improves resistance to pests and disease
Cultural controls	A,S,H,T	Reduce pest populations by manipulating farming practices, especially by intercropping and rotating crops
Biological controls	A,S,H,T	Reduce pest populations by using natural enemies
Pesticides	A,S,H,T	Reduce pest populations by using natural or synthetic biocides to kill pests, limit their fertility, or disrupt pest development
Post-harvest technologies	A,S,H,T	Improve processing and storage of foods; improve nutrition; reduce labor
Improving animal health		
Veterinary support	A,S,H,T	Reduces animal mortality and morbidity
Animal nutrition	A,S,H,T	Increases productivity; improves feed use efficiency; reduces susceptibility to disease

[a] See box 3-4 for a map of Africa's agroecological zones.

[b] Key to agroecological zones: A = Arid/Semi-Arid, S = Subhumid Tropical Uplands, H = Humid Lowlands, T = Tropical and Subtropical Highlands.

SOURCE: Office of Technology Assessment, 1988.

An important consideration in choosing the technologies reviewed in this report was their likelihood of being adopted by resource-poor agriculturalists, including influences such as expense, accessibility, and cultural acceptability. Some technologies already are in use, but show potential to be improved (e.g., made more productive, easier to use, or less expensive). Others are relatively new, but agriculturalists are likely to accept them because the technologies are well-matched to their needs and resources. Accordingly, promising technologies are judged by their ability to be:

- *Technically and environmentally sound.* This means they are able at least to stabilize, if not increase, production while conserving natural resources.
- *Socially desirable.* This means promising technologies address farmer-identified problems and operate within the constraints faced by farmers, and that they attempt to minimize the disruption of existing farming systems. It also means technologies are designed so farmers can take additional steps toward modernization as such changes become feasible.
- *Economically affordable.* This means that resource-poor farmers, herders, and fishers are able to obtain and maintain the technologies. Within the context of low-resource agriculture, this will generally emphasize the use of internal resources over externally purchased inputs.
- *Sustainable.* This means that it is feasible environmentally, socially, economically, and institutionally to maintain the technologies over the long term.

Also, the technologies discussed in the full report show potential in at least one of seven areas:

1. improving the use of local natural resources,
2. improving soil fertility,
3. improving water availability,
4. fostering genetic improvement in plants and animals,
5. improving integration of animal and cropping systems,
6. reducing food losses, and
7. enabling farmers to modernize as it becomes feasible for them.

Quantitative estimates of whether and how much these methods will increase agricultural production are difficult to make. Many past estimates have been misleading. The literature about experiments with crops and techniques is replete with examples that have not met expectations: a newly developed sweet potato that can yield at least six times the African average, and windbreaks that not only increase yields but supply valuable fodder and fuelwood. Yet adoption rates for improved varieties are low, freely supplied tree seedlings often go unplanted, and technologies developed under experimental settings are consistently less productive on-farm. Why? The answers range from farmers being unfamiliar with the practice to researchers being unfamiliar with the farmers, including the criteria used in accepting or rejecting new technology.

Nevertheless, it seems that sizable on-farm gains are possible using the types of technologies discussed here. For example, the U.N. Food and Agriculture Organization's (FAO) tests show that improved management practices alone can raise crop yields 20 to 80 percent. Full use of conservation measures could increase long-term productivity by 33 percent.

Just as important are estimates of how much current production may be lost if resource degradation continues. Africa could lose 16.5 percent of its rainfed cropland if degradation goes unchecked. Estimates of overall productivity losses reach 25 percent.

Also, however, qualitative benefits of many technologies can be as important as their potential to increase yields or prevent yield decreases. Stability of production from year to year is vital. And many practices can be used in combination, adopted piece by piece as farmers and herders can afford them.

This suggests a general sequence for supporting technological development. Efforts should first be directed toward improving and making available technologies that maximize the use of available, low-cost, renewable resources since these are usually more accessible than purchased inputs. For instance, efforts to improve water use could first be directed at making more efficient use of freely supplied rainwater through improved management, then moving toward systems such as contour planting, water harvesting microcatchments, and tied ridges that require some structures or greater external inputs. These practices may produce only slight yield increases in average years, but their real advantages show during drought years, when technologically improved fields are able to maintain yields when other fields fail. A last step in this continuum would be the adoption of small-scale irrigation technology, which faces substantial obstacles because of its high costs and complexity.

Although OTA's analysis sees an important role for technology in the future of African agriculture, it is only one factor among many that must be considered. Technologies do not operate in isolation. Research to develop and adapt low-resource technologies must be accompanied by attempts to address many influential, nontechnical factors that operate at the national and farm level. Agricultural prices, land tenure, conservation policy, household dynamics, and women's roles, for example, all affect use of technology.

THE ROLE OF FOREIGN ASSISTANCE

The United States has the potential to play a major role in enhancing low-resource agriculture in Africa, but whether this role will be pursued to its full extent has yet to be determined. The decisions made by Congress and executive branch agencies will be important in determining the U.S. role.

Congress faces a number of critical decisions concerning development assistance to Africa, with conflicting pressures to take several different routes. Some urge continuing support for existing foreign aid legislation. Others, especially within the current Administration, advocate a new macroeconomic approach that focuses on policy reform and might suggest amending current legislation. A third possibility—one influenced by domestic budget concerns and the perception of the ineffectiveness of previous development assistance—would decrease overall foreign aid.

Congress and a Resource-Enhancing Approach

Many goals of existing legislation already support a resource-enhancing approach: they call for participation of the poor in their own development, they note the need for women to be included in development efforts, they stipulate that U.S. aid prevents environmental degradation, etc. Congress has not provided clear direction on priorities among different and sometimes conflicting goals, however. And food security, a critical need in Africa, has not been an explicit, high-priority goal. Making these clarifications would provide a stronger basis for enhancing low-resource agriculture in authorizing legislation.

Long-term commitments are necessary for many key elements of a resource-enhancing approach, such as research, training, and institution-building. Stable, long-term levels of funding, with certain reduced restrictions on its use, are among the most supportive actions that Congress can take in its appropriations activities. Current funding mechanisms, such as authorizing and appropriating several different sources of funds administered by a number of different bureaus within the U.S. Agency for International Development (AID), and ongoing attempts to reduce the Federal budget may restrict Congress' ability to provide long-term, stable funding, however.

The Development Assistance (DA) fund, administered bilaterally by AID, may be the most suitable funding source for supporting low-resource agriculture. Development is its major goal and its appropriations are less volatile than others (e.g., food aid and economic support). But in the past, DA for Africa has not received attention equivalent to that of Economic Support Funds (ESF; also administered by AID) and food aid.

Congress reversed the erosion of assistance to Africa in fiscal year 1988 with the creation of a special African development fund with a 1-year appropriation of $500 million. Its impact cannot yet be determined but its success will depend on whether Congress maintains its commitment to a separate fund for Africa in the future, on how AID uses the fund's provisions for increased flexibility, on whether AID and Congress ensure that funds are not diverted to other programs, and on whether the fund is used to support low-resource agriculture.

AID, the World Bank, and other assistance agencies are often criticized for their inability to support resource-poor agriculturalists. Yet Congress already has mandated many elements of a resource-enhancing approach and has appropriated funding that could be used for this purpose. Therefore, perhaps the most crucial congressional responsibility is oversight to ensure that funds and policies intended to enhance low-resource agriculture are used effectively.

Detailed oversight will be necessary to ensure that donor activities are indeed supportive of resource-poor farmers and herders but constraints on staff time and committee jurisdiction may make this difficult. Increased cooperation among the seven committees with direct jurisdiction over U.S. agricultural assistance, an improved database on AID expenditures in Africa, and AID/Congress development assistance working groups could save staff time and improve the quality of congressional oversight.

With more effective oversight, some potentially burdensome congressional restrictions on AID might be reduced. These include requirements for notification regarding reprogramming funds, procurement requirements, restrictions on aid to specific countries and commodities, and earmarked funds. The legislation creating the new African development fund relaxed some of these congressional requirements. It provides an important test of the benefits of such an approach, including how well AID can implement congressional intent without detailed earmarking for guidance.

Three Categories of Assistance

To implement a resource-enhancing approach to African agriculture, development assistance must support three types of activities, involving a range of donor and African organizations with different strengths and weaknesses:

- local-level work, where activities would include support for local institutions, households, and individual agriculturalists;
- support for formal agricultural institutions necessary for agricultural development, where activities would include research, education, extension, and marketing; and
- national-level work, where activities would include assistance for supportive national policies and national capabilities to create and implement them.

Local organizations, often comprised in part of the resource-poor agriculturalists for whom assistance is intended, will play key roles in development assistance. These groups range from informal, self-help groups to more formal ones. Their participation is likely to increase the relevance of development activities to local conditions, increase its cost-effectiveness, and increase its sustainability over the long term.

Major donors have been largely ineffective working at the local level. Many donors have failed to tap the potential of local organizations and sometimes have made overwhelming demands on local groups and thus, undermined the groups' effectiveness. Yet the needs of local groups are large enough that they may require the resources available only from major donors. In that case, the Peace Corps, U.S. private voluntary organizations, and similar groups have the potential to act as intermediaries between the larger donors and local groups in addition to implementing their own sizable local-level programs.

Other high priority activities will be developing and improving agricultural research and training institutions. The major bilateral and multilateral donors are best able to provide the comparatively high levels of long-term funding needed for this type of development. AID, in particular, has a comparative advantage in tackling these activities. Special efforts will be needed, however, to ensure that training and research are responsive to the particular needs of resource-poor agriculturalists. For example, training will need to build understanding of how low-resource agriculture works, ensure that women receive adequate training, provide as much training as possible in Africa, ensure that curricula are relevent to African conditions, and combine U.S.-based work with support for research for Africans in Africa.

Support for building institutions has had limited success in Africa, whether funded by U.S. AID or the World Bank. Recent improvements, however, suggest that both may be more effective in the future. AID's 1985 "Plan for Supporting Agricultural Research and Faculties of Agriculture in Africa" is one element of AID's institution-building approach. Many of its features are supportive of a resource-enhancing approach, for example, the need to build African technical capabilities and for long-term technology development. Questions remain, however, regarding the apparently minor role of farming systems research in this approach and whether its narrow geographic and commodity approach is suitable.

National policies that support agriculture and resource-poor agriculturalists are necessary if low-resource agriculture is to be enhanced. Major donors such as AID and the World Bank

Photo credit: Donald Plucknett/Consultative Group on International Agricultural Research

Support for agricultural research is an appropriate priority for U.S. development assistance. U.S. contributions helped the International Institute of Tropical Agriculture and the Rwandan national research program provide these farmers with improved cassava varieties.

have significantly increased funding in recent years to support reforms of national policies. These changes have had ambiguous results concerning their impact on increased food security for resource-poor farmers and herders. Therefore, support for sweeping reforms may be unwarranted until donors improve their understanding of these impacts and examine the actual policy needs of resource-poor farmers and herders. The World Bank has the analytical capabilities to lead such an effort.

AID and a Resource-Enhancing Approach

AID is the principle U.S. agency that would bear responsibility for implementing a resource-enhancing approach to development assistance in Africa. The Agency's current overall strategy for African development could be compatible with such an approach, but full implementation would require substantial changes in priorities, operations, and general philosophical approach. For instance, AID would have to ensure that strategy papers, such as ones supporting women in agriculture and addressing environmental sustainability, are implemented more effectively and that Africans assume a larger responsibility for carrying out U.S. aid. In addition, AID's current emphasis on increased funding for policy reform might need to be lessened considering the impact such reforms have had on resource-poor agriculturalists.

Over the past few years AID has made changes that could help the agency enhance low-resource agriculture, including more decentralized decisionmaking, increased attention to research, longer term support for projects, and an increased emphasis on projects' sustainability. At the same time, the impact of these shifts may be offset by deep personnel cuts, a lack of appropriate technical personnel, inadequate language and cultural skills, a flawed reward system, and a project design system that is cumbersome, inflexible, and oriented to achieving short-term results. These latter constraints were identified long ago and have remained unresolved. Therefore, their remedy would require concerted effort on the part of the Administrator and all AID staff.

The Road Ahead

The decision to assist resource-poor African farmers and herders is not made in isolation within AID or within Congress. Broader U.S. policy concerns direct congressional decisionmaking and these reflect a variety of American concerns.

For example, U.S. farm trade suffered an overall decline in the 1980s with some commodities losing market shares to foreign competition. Recent legislation, passed with the backing of some U.S. farm groups, curtails U.S. support for certain crops in developing countries due to concerns that such support helped those countries improve their competitiveness. Newer analyses, however, suggest that stimulating African development will have greater long-term benefits for U.S. agriculture than attempts to limit U.S. technical assistance to African farmers. They need higher incomes to buy American products and higher incomes will require greater agricultural production. Yet pressing concerns regarding the health of the U.S. farm sector and trade balance are likely to override longer term considerations.

Also much of the American public has little awareness of the costs and benefits of U.S. development assistance and perceives that the United States spends too much money on foreign aid; some believe that as much as 40 percent of the U.S. budget goes to development aid. In fact, the correct figure is no more than 1 percent and has declined steadily since the 1940s. Almost inevitably, comparisons are made to the successes of the Marshall Plan to rebuild war-torn Europe when problems were simpler to solve and more resources were available.

Whether the United States invests too much or too little in meeting its interests in Africa is a subject that will continue to be debated. Expectations that dramatic results are possible are misguided, though, even if increased funding was available. The road to African food security is a long and difficult one. Decisions on how to address the challenges ahead are African ones. Clearly, however, U.S. foreign assistance legislation states that the United States will be a partner in this process. And an approach that enhances low-resource agriculture will be an essential component of any effective U.S. development assistance effort.

FINDINGS AND OPTIONS

Congress can shape U.S. development assistance in a number of ways. This chapter addresses how Congress can use these methods to improve the effectiveness of U.S. aid and enhance African agriculture (table 1-3).

Finding 1: Low-resource agriculture—farming, herding, and fishing—is the predominant form of African agriculture, a largely untapped development resource, and a necessary starting point for meeting future food security needs.

Agricultural development is recognized as key to African economic development, that is, meeting food needs, maintaining and increasing rural employment, and stimulating the internal economic markets necessary for nonagricultural growth. Low-resource agriculture is the predominant form of agriculture throughout Sub-Saharan Africa and experts believe that it will remain the mainstay of African agriculture at least for the short to medium term. But low-resource agriculture, as it now exists, is neither capable of meeting Africa's food and employment needs nor of keeping up with growing populations and environmental degradation. Thus, any broadly based plan for African agricultural development must find ways to enhance low-resource agriculture.

Resource-poor African agriculturalists are rich in local resources, such as skills, knowledge of indigenous plants and animals, understanding of the environment, and indigenous institutions. Agricultural development strategies have consistently bypassed these resources, sometimes contributing to their loss, often to the detriment of aid's effectiveness. More successful agricultural development depends, in part, on tapping these resources by developing methods to identify and use them.

However, the United States has no overall policy for enhancing low-resource agriculture in Africa despite the importance currently given to providing agricultural assistance. For instance, AID's current strategy for Africa lacks many features necessary for such an approach. In practice, development assistance commonly either has not addressed low-resource agriculture or attempts have been made to improve it in inappropriate ways. Most donors have not developed the methods needed to improve low-resource agriculture. Developing a strategic plan for enhancing low-resource agriculture would bring proper focus to its current status and potential and contribute to development and implementation of needed methods.

Many strategic questions regarding the U.S. role in development assistance are being debated now. For example, a significant number of organizations are taking part in a 1988 effort coordinated by Michigan State University. Its goal is to help shape U.S. development policy in the 1990s. Also, the U.S. foreign assistance legislation is under continuing scrutiny regarding its overall goals and their implementation. The appropriate role of macroeconomic policy reform, a major Administration focus, is one debated topic.

Such efforts will affect any U.S. approach to enhancing low-resource agriculture, but they do not provide the detailed guidance for that work. Therefore, the U.S. development assistance community needs to give specific attention to the strategic aspects of work that focuses on resource-poor farmers, herders, and fishers. This need is most acute for AID, the primary provider of U.S. development assistance. But other organizations using U.S. funds for agricultural development, private groups, additional U.S. agencies whose work affects devel-

Table 1-3.—Findings and Congressional Options for Enhancing Low-Resource Agriculture in Africa

Findings	Options
1. Low-resource agriculture is the predominant form of African agriculture, a largely untapped development resource, and a necessary starting point for meeting food security needs.	1a. Assign AID the lead role in developing and coordinating a U.S. approach to enhancing low-resource agriculture. Support an international/interagency conference to set out such a strategy and follow up with agency 5-year action plans. 1b. Request that AID and the World Bank (through the U.S. Department of Treasury) evaluate how policy reform could best serve the needs of low-resource agriculture. Base continued support for and direction of reform on these evaluations.
2. Strengthening African research, education, and training is one of the most effective and sustainable contributions that the United States can make.	2a. Support the long-term development of African agricultural institutions. Oversee AID and World Bank activities to ensure this work assists resource-poor agriculturalists. 2b. Support increased formal education and training of Africans in ways that enhance low-resource agriculture.
3. Improving low-resource agriculture entails work at the local level. Supporting local African groups and intermediary organizations is one way of working at the local level. The Peace Corps and private voluntary organizations (PVOs) also can work locally and can act as intermediaries between large donors and local groups. These intermediaries could be strengthened by improved technical support and evaluations.	3a. Direct AID to develop technical support mechanisms for indigenous African organizations, PVOs, and the Peace Corps. These mechanisms could draw upon universities and research centers (African, U.S., international) and private organizations. 3b. Request that the Peace Corps develop and implement an ongoing evaluation system.
4. Congressional oversight will be crucial for implementing a resource-enhancing approach since legislation and funding mechanisms are already in place. Changes in oversight will be necessary to increase its quality while reducing the burden it places on AID.	4a. Ensure that all funds provided for the new bilateral development fund for Africa are used for development purposes. Oversee that other types of agricultural funding support low-resource agriculture. 4b. Improve oversight activity and smooth the AID/Congress working relationship. 4c. Reduce the restrictions on the use of development assistance. Monitor the impacts of newly made reductions.
5. Long-term commitments and stable funding levels are necessary.	5a. Maintain stable appropriations for development assistance. Emphasize Development Assistance within bilateral assistance. Continue policies of appropriating a special development fund for Africa and significant U.S. contributions to the International Development Association of the World Bank. 5b. Encourage AID to address a set of internal constraints. AID could evaluate the impact of its operational structure and procedures on its development work, then begin institutional reforms.

SOURCE: Office of Technology Assessment, 1988.

opment, and African groups at all levels need to be involved in developing this approach.

Option 1a: Congress could assign the Agency for International Development (AID) the lead role in developing and coordinating a U.S. approach to enhancing low-resource agriculture in Africa. To help develop such an approach, Congress could support an international/interagency conference to assess the status of current programs and set out a general strategy, under the auspices of AID. Participating organizations could prepare and implement 5-year action plans subsequently

Interagency approaches to facilitate a foreign assistance strategy have worked in the past. AID and the State Department, for example, led the development of U.S. foreign assistance strategies for tropical forests and maintaining biological diversity. Both plans included strategy conferences that brought together researchers, policymakers, and practitioners; highlighted the importance of an issue that had not received adequate attention; underscored major areas of concern; and identified avenues to address those areas. Interagency task forces then defined specific U.S. efforts and individual agencies developed action plans to implement the strategies developed by the conference and task forces.

A similar strategy conference on how to enhance low-resource agriculture in Africa could bring a wide variety of organizations together to discuss U.S. priorities, compare successful methods, determine areas of collaboration, and identify important research topics. OTA's work suggests that several issues need to be addressed by such a group:

- assessing the comparative advantages of different donor organizations;
- developing relevant technologies;
- supporting the development of formal African agricultural institutions (e.g., universities, research centers, markets, policymaking bodies) and the trained personnel to staff them;
- supporting the development abilities of local African organizations; and
- supporting the development and implementation of relevant agricultural policies.

These topics are not new and have been addressed before. Using a specific resource-enhancing framework would be essential to breaking new ground. To do so, conference planning and subsequent implementation should be based on analytical criteria of:

- *sustainability*—environmental, economic, institutional, and technical;
- *diversity and flexibility*—accommodating the diversity of resource-poor farmers and the conditions they face, and the flexible ways in which they respond;
- the use of *local resources* of the resource-poor farmers, herders, and fishers which includes methods of fostering their participation in development; and
- accounting for the ecological, social, and economic components of the farming *systems and their off-farm links*.

AID should host this meeting because it is the agency ultimately responsible for carrying out most of U.S. development assistance. However, substantial efforts must be made to draw on other expertise, divergent views, and imaginative suggestions from a variety of groups and, as such, much of the conference planning should be assigned outside AID. Broad participation also could ensure that the meeting has an impact throughout the U.S. development assistance community. The Peace Corps, the African Development Foundation, the World Bank, private voluntary organizations, universities, and relevant executive agencies (the Departments of Agriculture, Commerce, and Treasury, etc.) should participate.

Significant African representation would be crucial before and during the conference to ensure that the work addresses African conditions and that an expanded role for African organizations is included. Members of Congress and their staffs could participate to contribute a congressional perspective. And a significant number of women must be included—whether they represent Africa's large number of women farmers or are drawn from the community that serves women farmers.

Task forces grouped around individual topics, like those associated with earlier strategy conferences, could be formed to continue working after the conference and to maintain communication among groups. Individual agencies could develop action plans to define their specific responsibilities and priorities, means for interagency cooperation, and funding requirements. These action plans could be incorporated into agency policy and planning documents. Congress could consider these plans as it both sets and oversees development priorities.

Option 1b: Congress could request that AID and the World Bank (through the U.S. Department of Treasury) perform in-depth analyses of how policy reform could best serve the needs of African resource-poor farmers and herders. Continued support for and future *directions of reform activities could be based on these evaluations.*

Support for policy reform quickly has become a large component of development assistance. By 1987, reform-related lending made up 35 percent of AID Africa Bureau's agricultural loans and 55 percent of the World Bank's commitments to Africa. Needed reforms have been known for some time but evaluating the effects of donors' activities to stimulate such reform is comparatively recent.

Evaluations are incomplete and ambiguous concerning policy reform's effects on resource-poor farmers and herders. However, evaluations have raised concerns regarding reform's: lack of grounding in actual, local agricultural conditions; its potential to harm large segments of the poor; and its lack of emphasis on building African capability to carry out and continue policy reform once donor's efforts diminish. Also, evaluations have called for additional research addressing these concerns. For example, research is needed to identify methods that link macroeconomic reforms with conditions at the microeconomic level. Without such methods, macro-level reforms may not match micro-level needs (e.g., for removing local technical or marketing obstacles) and adverse local effects of macro-level reforms may be difficult to identify.

Congress could stabilize or decrease reform expenditures until such analyses have been completed and policy reform activities modified as needed. In addition, Congress could consider what role the United States should have in reform activity.

The World Bank, because of its sizable staff of economists and its ability to marshall support from many donor countries, might be the most effective lead agency for researching and supporting policy reform. Such a lead agency could coordinate work and discourage individual donors' from sending contradictory signals to recipient countries. But any lead agency must be sensitive to the policy needs of resource-poor agriculturalists and the representatives to the World Bank may need congressional encouragement to promote such work.

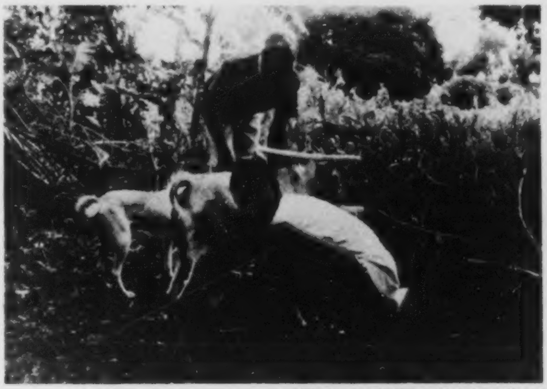

Photo credit: Winrock International

Concerns have been raised regarding the local impact that policy reform has on low-resource farmers and herders such as these in Kenya.

In the past, Congress has examined substantive issues of World Bank work via the U.S. Treasury Department, which directs the vote of the U.S. Bank Representative. For example, congressional hearings on World Bank activities during 1983-84 led the Treasury Department to perform an extended review of the environmental aspects of the World Bank's work. The Department actively promoted bank changes in this area as a result of its review. Congress could ask the Treasury Department to begin a similar extended review of the World Bank's policy reform work and accompany such a request with oversight hearings.

Congress could encourage AID to support a narrower set of policy-related activities that draw on AID's particular strengths. For example, U.S. strengths in training and institutional support could be directed to developing African abilities to analyze and implement agricultural policies that support low-resource agriculture. With these skills, African nations would be better able to develop and continue reforms over the long term.

Finding 2: Strengthening the abilities of Africans' to respond to their agricultural needs through research, education, and training is one of the most effective and sustainable contributions that the United States can make to African development.

Africans and donors alike increasingly see agricultural development as fundamental to overall African development. For agricultural development to occur, Africa will require its own strong agricultural institutions staffed by trained Africans, supported by its governments, and capable of responding to local concerns. For example, agricultural research institutions are necessary to develop, adapt, and improve technologies for resource-poor farmers, herders, and fishers; planning institutions are necessary to develop and implement supportive agricultural policies; and training institutions are necessary to prepare staff for these roles. Concurrently, governments must be ready to provide for recurrent and ongoing costs without which agricultural institutions cannot function: equitable salaries, upkeep, costs for travel, equipment, distributing reports, subscriptions to journals, etc.

In each case, the diversity of African agricultural systems requires technologies, policies, and training adapted to local social and environmental conditions. International organizations and those in the developed countries have neither the expertise nor the resources to meet so many differing local needs. Nor is development led by external groups likely to be sustained.

Donors do have a clear role to play in providing agricultural training for Africans and in supporting African institutions, however. The United States has a comparative advantage in these two areas and such work would be an appropriate U.S. priority. Past efforts in these areas often have not met the specific needs of resource-poor farmers, herders, and fishers and this problem must be addressed.

Option 2a: Congress could support the long-term development of African agricultural institutions capable of assisting resource-poor agriculturalists. As part of this support, Congress could oversee AID's 1985 research plan and the World Bank's work.

AID set out a coordinated approach in 1985 to support African research institutions and faculties working in agriculture. Known as the "Plan for Supporting Agricultural Research and Facilities of Agriculture in Africa," AID envisioned a commitment of significant resources (at least $100 million per year) over a 15-year span for supporting African research systems and faculties of agriculture, and backing cooperative research work through the international agricultural research centers and U.S. universities. The Plan is an important step in U.S. support of African capabilities both in the level of resources to be committed to this work and in its long-term approach—a departure from past, short-term efforts.

Congress could support this work in several ways. First, institution-building takes time, so congressional authorization and appropriations should provide resources for extended time periods and avoid unnecessarily introducing non-development interests that would slow work. Also, congressional oversight is essential on a number of issues:

- Is AID committed to implementing the Plan for its full term?
- Are established levels of funding being met?
- How is AID refining the Plan to meet African conditions?

Also, oversight is needed to ensure that the Plan actually addresses the needs of resource-poor agriculturalists, some of whom are now overlooked. For example, AID does not explain in detail how agricultural institutions can be linked to the needs of the farmer and herder, what their role in technology development should be, how to ensure the environmental sustainability of technology, how to address women's needs, nor how to make the best use of local resources. AID is currently reviewing the plan and a congressional oversight hearing could provide Congress with an update on its status while signaling to AID the need to address these points.

Congressional examination of the World Bank's support for agricultural institutions also is justified. The Bank's institutional support has been criticized as inadequate in quality and quantity. And a recently completed analysis of African research needs by the Bank highlights the importance of developing national research capabilities, but the Bank's approach suffers from many of the same weaknesses as AID's. Congress can make its concerns known via oversight and also could instruct the U.S. Treasury Department to advocate increased work by the Bank on building agricultural institutions.

The international agricultural research centers (IARCs) have an important role supporting African institutions. While primarily concerned with research, the centers could expand their training and institutional support. Any such expansion will require AID's continuing support to the centers. AID can also ensure that the centers gear more work to the needs of resource-poor farmers and herders.

Option 2b: Congress could increase support for formal education and training of Africans in ways that would enhance low-resource agriculture.

African countries will need increasing numbers of trained people (e.g., researchers and policymakers) to staff agricultural institutions. They will need training to assess the needs of resource-poor agriculturalists and to identify ways to meet those needs. Specific ways for the United States to be involved in this training could be determined at the strategy conference discussed earlier. New legislation or earmarked funds do not seem necessary but congressional oversight could ensure that education and training are priorities for U.S. development assistance.

U.S. universities could play a major role in education and training and U.S. support for these institutions will be an important contribution. Undergraduate education should be the responsibility of African educational institutions primarily. However, increased opportunities for graduate training could be offered in the United States.

Only certain U.S. institutions are equipped to address the particular needs of low-resource agriculture and a better match of African students and U.S. programs is necessary. Mechanisms to ensure the complementarity of training with the needs of African agriculture include tying U.S. graduate training to thesis research in Africa and providing increased training opportunities for African women. Also, AID could identify other appropriate programs that are particularly relevant to African conditions and tap those programs. AID-provided strengthening grants to U.S. universities could further the development of such programs where a commitment to low-resource work exists.

Assistance for training and education should continue once Africans who were students assume responsibilities in Africa. Small grants to begin research, travel funds for collaboration with senior scientists, and longer term "twinning" efforts between African and other institutions (e.g., U.S. universities, private organizations, and the IARCs) could ensure that trained Africans are able to make use of and update their education.

Finding 3: Enhancing the capabilities of resource-poor farmers, herders, and fishers will require support at the local level. Supporting local African groups and African intermediary organizations who provide services to these groups is one means of working at the local level. The Peace Corps and private voluntary organizations can work directly at the local level while also acting as intermediaries between larger donors (e.g., AID and the World Bank) and local groups. Improved evaluations and strengthened technical backup would increase the effectiveness of these intermediaries.

Agricultural development will depend, in part, on developing technologies appropriate to the diverse local conditions of Africa and matching technologies with the social organizations necessary to make use of them. Development of formal agricultural institutions and agricultural policies need to be linked to the local level to ensure their relevance to actual conditions. However, local African organizations, whose membership includes resource-poor agriculturalists, offer donors an additional means of reaching the local level directly. These organizations can initiate work appropriate to local conditions, mobilize local resources, and maintain work after outside assistance ends.

The Peace Corps and many private voluntary organizations (PVOs) have experience working with local organizations and they, along with African intermediary groups, could become important sources of support for local organizations. This might entail a shift from their current focus on implementing projects. Often, however, PVOs are technically weak and do not carry out the evaluations necessary to identify their particular strengths and weaknesses. Correcting these two problems is a prerequisite for providing more effective U.S. aid at the local level.

Larger donors such as AID and the World Bank commonly do not work well at the local level nor have they given much attention to the growing numbers of local African organizations. Their support of local groups may be necessary because the Peace Corps and PVOs do not command enough resources to match the growing needs of African groups. The Peace Corps, U.S. PVOs, and African intermediary organizations could, however, become important intermediaries between large donors and local organizations. But, evaluations of individual group's abilities to carry out effective low-resource work must precede their selection for funding.

Photo credit: Watson/U.S. Peace Corps

The Peace Corps, like many PVOs, works well with local groups such as this women's gardening cooperative in Mali. Better technical support and improved evaluations would ensure that this work is as effective as possible.

Option 3a: Congress could direct AID to develop technical support mechanisms to help PVOs, the Peace Corps, and others (including indigenous African organizations) identify, adapt, and promote promising technologies. Such mechanisms could draw upon the expertise of universities and research centers (U.S. and African), the international agricultural centers, and private organizations (African and U.S.). The goal would be to have these services in place within 5 years.

Members of the development assistance community, such as the Peace Corps, PVOs, and African organizations that have staff based in African communities, know the needs and abilities of resource-poor farmers and herders in ways that few others do. Often, however, these people lack the technical skills (including managerial and financial skills) needed to support agricultural development most effectively. The costs of developing and maintaining these skills for each group would be prohibitively high. Instead, a number of African and U.S. sources of technical expertise could be linked to local groups. This linkage should be two-way; for example, farmers' research needs should be passed to research centers as these groups provide technical information to farmers.

Some U.S. assistance has been effectively provided in this manner. For example, the AID-funded Forestry Support Program provides technical support benefiting AID missions and PVO-funded projects.

The importance of such efforts is likely to increase. African groups are increasingly able to assume direct responsibilities for implementing development programs. Some larger donors are cutting their field staff and relying more on PVOs. And Congress is reinforcing this pressure to channel significant amounts of U.S. development assistance through U.S. and African PVOs. Increasing the abilities of these groups to be technology brokers between technical experts (e.g., agricultural researchers) and groups of farmers and herders will improve their effectiveness. Support for groups that have demonstrably good results at the local level and for groups that focus on low-resource agriculture is important.

Option 3b: Congress could request that the Peace Corps develop and implement an ongoing system for evaluating its work.

The Peace Corps is considered effective in local-level work, providing skilled training for its volunteers. But the quality of its work varies across geographic regions and disciplines; its institutional memory is short; and long-term planning and implementation are difficult to carry out. The evidence for these strengths and weaknesses is largely anecdotal, however.

As conditions in Africa change, it will be important for the Peace Corps, which seems particularly effective, to keep pace. An ongoing evaluation program could help the Peace Corps identify areas of proven effectiveness, and then enable the agency to concentrate its resources there. Also, many weaknesses listed above are inherent in short-term, volunteer-based work. Project and program evaluations could seek ways to compensate for these problems. Evaluations might also address how well the Peace Corps might function as a technology broker, linking resource-poor agriculturalists with agricultural researchers.

Finding 4: Congressional oversight will be crucial for using development assistance to enhance low-resource agriculture. Appropriate legislation is already in place and many complementary changes in funding have been made. Changes in the way oversight is conducted may be necessary to increase its quality while reducing the burden it places on executive agencies, though.

The current legislation governing U.S. development assistance provides a mandate for enhancing low-resource agriculture. In addition, the 1987 creation of a separate, bilateral African development fund and corresponding reductions of restrictions on its use have stabilized funding and increased flexibility. Thus, Congress already has provided the basis for AID to improve how it addresses low-resource agriculture.

Criticism is likely to remain regarding AID and other donors' abilities to meet the needs of low-resource agriculture, however. Many argue that the needs of resource-poor farmers and herders have not been the focus of U S.-funded research, training, and institution-building programs. Oversight will be needed to ensure that U.S.-funded donors respond to this criticism and, where necessary, sharpen this focus.

Current forms of oversight have not proven adequate to this task and evidence exists that oversight sometimes has impeded the work of donors due to its excessive demands. Thus, Congress could revise oversight procedures to increase the quality of information provided while reducing the burden on agencies providing it. In 1987, Congress made several such changes by reducing a number of restrictions on AID's operations regarding procurement, earmarks, and program funding. These reductions will need to be monitored for their impact on AID's efficiency and to evaluate how well AID carries out congressional intent with this more flexible guidance from Congress.

Option 4a: Congress could oversee that all the funds provided in the new African development fund are used for development objectives and that agricultural funding supports the improvement of low-resource agriculture. Oversight for the latter also could be applied to other U.S.-supported organizations such as the World Bank.

Congress created a separate development fund for Africa for fiscal year 1988 totaling $500 million. The fund provides more stable levels of African development assistance (and may continue to do so if maintained in the future), helps protect this funding from use for short-term political objectives, and provides AID with increased programming flexibility since it contains few restrictions for the use of funds.

If the fund's potential benefits are to be realized, however, Congress will need to ensure that the monies appropriated are not diverted from development aid. In addition, the fund sets no levels for spending on agriculture. AID has made agriculture a focus of its assistance for Africa but Congress could monitor whether the percentage of funds used is adequate.

The existence of this or any other fund is not adequate to ensure that U.S. assistance enhances low-resource agriculture. Donor agencies receiving the majority of U.S. development assistance funds undoubtedly have the capacity to support such development. Yet evaluations show that AID and the World Bank have weak records concerning the development of technology appropriate for resource-poor farmers and herders; that their track record is poor for supporting the development of African institutions able to address low-resource agriculture; that their training programs are missing important opportunities; and that links between their policy reform work and the local level are weak. In particular, questions exist whether the development assistance community is taking advantage of the opportunities offered by African organizations, including local ones. Therefore, congressional oversight of substantive issues such as these will be necessary to ensure that funds are provided for agricultural development and also used to address the needs and abilities of resource-poor agriculturalists.

Option 4b: Congress could make improvements to its oversight activities and smooth the AID/Congress working relationship.

A need exists for in-depth, long-term oversight on substantive matters. This need conflicts with the time available to Congress and with the more general expertise of Members of Congress and their staffs. Small staffs oversee large executive branch programs annually, often in conjunction with other duties. If inadequately prepared, oversight can provide little useful information to Congress and absorb development resources that could be spent on implementing programs.

This problem is aggravated by the many congressional actors involved in oversight. For example, seven committees and additional subcommittees have direct jurisdiction over development assistance and Members often take part on an individual basis as well. As a result, AID (the agency most affected) often responds to a multitude of congressional requests which may be duplicative or contradictory. These problems are exacerbated by the somewhat adversarial relationship between Congress and AID.

A number of methods are available to improve the substance of oversight, cut its undue costs, and reduce problems in communication. For example, an informal task force of authorizing and appropriations committee and subcommittee staff could help coordinate oversight and reduce redundancy. Such a task force might also be a forum for a detailed examination of development issues and new approaches. It could tap outside expertise in this process, especially that of Africans visiting the United States.

Another means to provide specialized expertise to staff would be to form a group of experts in development work to help oversee U.S. multilateral and bilateral development assistance policy. Such a group could be constituted informally or more formally established as a Development Assistance Study Institute. Such an institute could provide a forum for congressional members and staff to meet with executive agency personnel and other groups to focus oversight and gain substantive input into the process. An institute such as this could be a new body or an addition to an existing one, such as the Energy and Environment Study Institute.

An AID/Congress forum could be established under these or other auspices. An AID task force could identify congressional constraints on its work and a corresponding congressional group could identify high-priority oversight issues for AID to address. This forum could begin an ongoing process for resolving some of the underlying strains between AID and Congress.

Oversight also could be improved by increasing the availability and relevance of specific information on U.S. assistance. For example, Congress could request AID to improve its database on its agricultural work in Africa. Currently, AID is unable to provide such information. At the same time, Congress needs to make its data needs clearer so as to reduce the amount of data generated by AID in anticipation of congressional needs that do not materialize.

Option 4c: Congress could reduce restrictions on the use of development assistance funds in order to increase its efficient use, while monitoring the impact of newly granted flexibility.

Congress has placed a variety of restrictions on how AID implements development assistance. In some cases, these restrictions have direct costs to AID, for example, it devotes money and staff time to notifying Congress regarding reprogramming of funds and to providing mandated reports. AID has testified that at least 200 annual staff-years are devoted to preparing materials for Congress and dealing with various congressional groups. In other cases, AID's costs due to congressional limits are less direct, for example, procurement requirements may increase the cost of overseas purchases, appropriations earmarks may require more detailed accounting, and restrictions on aid to individual countries and commodities may decrease the overall effectiveness of AID's program. Also, AID responds to more informal congressional pressure to achieve multiple (sometimes incompatible) goals and to use assistance for non-development purposes. Congress and AID could streamline this process so that more of these resources could be spent on development.

Congress made several legislative changes in 1987 to reduce restrictions on AID's assistance to Africa: reprogramming and procurement restrictions were reduced and the number of earmarks was significantly cut. If these changes prove effective, Congress could increase AID's flexibility further by providing no-year money, reducing additional earmarks, etc. Also, complementary changes could be made to define priorities among the multiple mandates in the Foreign Assistance Act to reduce non-developmental pressures on the use of assistance.

At the same time, Congress needs to monitor carefully how AID makes use of its increased flexibility. Granting increased flexibility to AID may enable more efficient and effective use of its resources. However, it also increases the risk that congressional priorities for development assistance may not be followed fully. AID's past inability to address the needs of resource-poor farmers and herders contributes to concern over this issue. Again, this emphasizes the need for substantive and thorough oversight. Congress could ensure that continued flexibility depends, in part, on AID's responsiveness to broad congressional direction for development assistance.

Photo credit: F. Mattioli/U.N. Food and Agriculture Organization

Improved management of land and water resources is an important part of enhancing low-resource agriculture. This is recognized in the new African Development Fund, an attempt by Congress to provide flexible guidance and fewer restrictions for AID while still specifying general priorities.

Finding 5: Long-term commitments and stable funding levels are necessary for donor agencies to provide effective development assistance, especially for enhancing low-resource agriculture.

Many development assistance goals identified by OTA as necessary for African agricultural development cannot be reached quickly nor if development assistance funding undergoes large and unpredictable swings. Research, agricultural institution-building, and supporting the development of local organizations are all long term in nature. Development assistance for these purposes must be correspondingly long term. And stable levels of aid are important for planning long-term work. Unanticipated fluctuations in aid, whether caused by changes in overall assistance funding or by changes in political goals, reduce the effectiveness of aid. Such swings have stopped successful efforts and ended other work before results could be achieved.

Option 5a: Congress could appropriate stable levels of bilateral and multilateral assistance for Africa. For bilateral assistance an emphasis on Development Assistance would best support such long-term stability, a continuation of the 1987 policy creating the development fund for Africa and increasing U.S. contributions to the International Development Association of the World Bank.

U.S. bilateral agricultural assistance to Africa is provided primarily through three AID-administered funding sources: Development Assistance, Economic Support Funds (ESF), and food aid. Of the three, Development Assistance is the most suited for providing stable levels of funding in support of a long-term approach. U.S. legislation regarding development generally supports enhancing low-resource agriculture. Also, Congress provided the means to maintain stable funding levels for AID's African Development Assistance account by creating the new development fund for Africa. Previously, African funds were held with worldwide development funds and were vulnerable when discretionary funding was reduced due to earmarks for aid to other regions.

The other funding sources continue to be held in common. They are less appropriate for providing long-term stable support for this and other reasons. ESF usually are provided to recipients for political and security reasons and tend to be volatile. Africa's needs are seen as less pressing than those of other regions. Food aid can fluctuate substantially due to changing emergency needs in Africa and U.S. food surpluses.

While Development Assistance may be the most appropriate form of aid for African social and economic development, the United States sometimes has not made it the primary source of African assistance. Between 1980 and 1985, ESF to Africa tripled thereby exceeding Development Assistance funding, which had increased by one-fourth. This decline in the relative importance of Development Assistance took place as worldwide U.S. foreign assistance doubled, primarily through increases in ESF and military aid.

With declines in total foreign assistance in 1986 and 1987, ESF to Africa was severely cut and Development Assistance became the predominant source of funding to Africa. Yet the cuts in Development Assistance and ESF put 1987 funding to Africa close to 1980 levels. The $500 million appropriated for the development fund for Africa in fiscal year 1988 (and also an additional $50 million for projects of the Southern Africa Development Coordination Commission) halted the decline in Development Assistance for Africa. If maintained, the fund could provide the means for stabilizing Development Assistance to Africa for the long term.

U.S. support of multilateral development organizations has also fluctuated, with some exceptions. The International Development Association (IDA) of the World Bank provides concessional loans to the poorest countries. United States IDA funding fluctuated from a high of $1 billion to a low of $520 million between 1980 and 1987. The U.S. agreement to provide $2.875 billion over the next 3 years, along with congressional appropriations of $915 million for fiscal year 1988, will help stabilize IDA funding to Africa, assuming that appropriations continue at agreed-upon levels.

U.S. support for the African Development Fund, the concessional loan window of the African Development Bank, has had fairly stable funding since 1986. Funding for the United Nations development agencies that receive voluntary U.S. contributions (e.g., the United Nations Development Program and the International Fund for Agricultural Development) increased between 1980 and 1985 but declined significantly in 1986 and 1987. The U.N. Children's Fund was an exception; its funding has remained relatively constant since 1984.

Maintaining stable funding over the long term is made difficult by the annual congressional authorization and appropriations process. Longer term authorizations and appropriations (possibly 2 to 4 years) would help set stable funding levels, allow agencies to do long-term planning, help protect development funding from shifts in funding or diversions to other uses, and free Congress to spend additional time conducting oversight.

Option 5b: Congress could encourage AID to address a set of internal constraints that hinder effective implementation of development assistance. First, AID could evaluate the effect its operational structure and procedures have on its development work. Then, Congress and other organizations could help AID develop and implement internal reforms.

AID has made a number of positive operational changes that could increase the effectiveness of its development assistance activities overall, especially as they relate to resource-poor farmers and herders. These include increased roles for field missions, funding longer projects, and strengthening its evaluation and information system. Past OTA work has identified a set of internal constraints that may undercut the benefits of these changes:

- The numbers and skills of AID's Africa staff are not commensurate with the U.S. commitment to Africa. Significant staff cuts in the 1980s have worsened the problem. Technical, local language, and cultural skills largely are lacking. High rates of turnover interrupt program continuity, make accountability difficult, and reduce institutional memory. Local staff are often underused.
- Program and project design systems tend to be slow and inflexible, and they tend to reward the project designer and obligator of funds rather than the successful implementor. Obligating funds can be quick but project implementation can be held up by paper requirements and procurement bottlenecks.
- Program and project monitoring is constrained by a small staff. Evaluation results may be too narrowly focused and ineffectively incorporated into the design process.

These constraints are well known. Some consider them to have worsened with time. Growing concern has led some observers to conclude that AID lacks the commitment to remedy these problems or is incapable of doing so and the best solution would be to restructure the provision of U.S. assistance substantially, to form a new development agency, or to transfer certain AID functions to other organizations. While OTA did not analyze the appropriateness of these options, current budget restrictions and difficulties in passing foreign assistance legislation suggest that such drastic changes are unlikely. Thus, resolving AID's constraints depends primarily on AID/Administration action.

Part of the problem is influence exerted by interests outside of AID (for example, political concerns of the U.S. Department of State, short-term economic interests of American exporters) that sometimes hamper development work, and Congress may wish to examine these competing pressures. Notwithstanding such external influences, AID has not been effective in resolving well-recognized internal problems. Congress could focus AID's attention on the need to address and provide support for internal reforms. If such reforms are not successful, then alternative, perhaps more extreme, options could be considered.

Chapter 2

Prologue

CONTENTS

Page

The Critical Need for Food Security 35

Issues Beyond the Scope of This Assessment........ 35

Toward Enhancing African Agriculture 38

Chapter 2 References 39

Box

Box *Page*

2-1. AIDS in Africa: Will It Affect Agricultural Development? 37

Chapter 2

Prologue

In view of two decades of acute and chronic food scarcities in much of Africa, and projections of a doubling of population in 25 years, the question arises whether Africa will ever be able to provide enough food for its people. The magnitude of the challenge ahead is reflected by one alarming trend: overall food production in Sub-Saharan Africa in the last decade has increased only about half as fast as population growth although the record is uneven, with food surpluses existing in some areas. Food self-sufficiency has deteriorated in virtually every country (13). Twenty years ago Sub-Saharan Africa was a net exporter of basic food staples, exporting an average of 1.3 million tons a year between 1966 and 1970. By the mid-1980s the region was importing some 10 million tons per year (9). Cereal self-sufficiency alone has dropped from 94 to 82 percent in the past 15 years (14).

THE CRITICAL NEED FOR FOOD SECURITY

Lack of food self-sufficiency need not be a serious problem per se, so long as production of other goods and services provides adequate income to acquire food from elsewhere. Food security, not food self-sufficiency, becomes the key goal. Food security can be defined as access by all people at all times to enough food for an active, healthy life and it depends on both the availability of food and the ability to acquire it (16). Improving food security involves increasing food supplies in addition to increasing poor people's real income, thus giving them access to food in national markets or through imports. Simply ensuring adequate national production contributes little to food security if people lack the ability to purchase what they cannot produce themselves.

African economies are heavily dependent on agriculture. In most countries in Sub-Saharan Africa, 70 percent or more of the labor force is in agriculture. Under these circumstances declining food self-sufficiency, as a function of declining per capita food production, is reason for concern. Most disturbing is the prospect that Africa's most vulnerable populations will become even more vulnerable and more Africans will be in this precarious position.

This report focuses on promising technologies to enhance low-resource agriculture in Africa and how U.S. assistance, with the support and direction of the U.S. Congress, can support African initiatives to meet food security needs. However, several issues that are not covered by this assessment directly and indirectly affect the African governments' ability to deal successfully with low-resource agriculture and other food security needs.

ISSUES BEYOND THE SCOPE OF THIS ASSESSMENT

Achieving food security requires solving a two-part equation, one of food production (the supply side) and one of the ability to buy food (the demand side). OTA's charge was to look at technology in support of food production in Sub-Saharan Africa, and thus this report focuses on the production side of the food security equation. Notwithstanding this emphasis, OTA finds strong agreement with the suggestion that:

> More research is needed on the demand (food access) side of the equation in light of the coexistence of malnutrition and food surpluses in the region. High priority food security research priorities are: marketing, trade, exchange rate policies, household food security

in low rainfall areas, the effects of market liberalization on the food security of various groups in society and research on institutional innovations that increase access to food (12).

Further, this report does not address many of the difficult challenges faced by African governments in balancing the needs of promoting food production with other development needs. Many governments face serious difficulties of providing basic city services under the pressure of the most rapidly growing urban populations of any region in the world (1). Many governments also will need to deal with concerns over an "urban bias" whereby food prices are kept artificially low in order to appease more politically vocal urban constituents, at the expense of rural food producers. Population and refugee problems are also serious in many areas. Degradation of the natural resource base as increasing numbers of Africans overwork the land or are forced to move onto increasingly marginal land is just one manifestation of these problems. Recent concerns of the potentially devastating impact of an AIDS epidemic in Africa (box 2-1) will also demand immediate attention and compete for scarce government resources.

Progress in developing Africa's low-resource agricultural sector will also be affected by international factors which African governments alone can do little to control. Countries in Sub-Saharan Africa suffered perhaps more than any other region as a result of global recession in the early 1980s. Beyond the obvious stress placed on funds for development assistance, was the serious impact of decreased international demand for Africa's exports.

Terms of trade have generally been declining for most African countries. Prices have fallen for most of Sub-Saharan Africa's major export products while, on balance, prices have risen for imports. Countries in the region are particularly vulnerable because export earnings depend on one or two commodities (e.g., coffee, cocoa, or cotton). The high level of diversity manifest in traditional African agricultural systems has never translated into the export arena. In fact, over the last several decades African countries have become increasingly dependent on fewer commodities for export earnings (13). As with farming systems, one consequence of little diversity is increased vulnerability. Further, most of Sub-Saharan Africa's agricultural export earnings are derived from commodities with low price elasticity of demand. For a number of the most important export commodities, including coffee and cocoa that together comprise nearly half of the region's agricultural export earnings, increased export volume may actually reduce earnings. Thus emphasis on expansion of African agricultural exports without diversification is unlikely to greatly improve African export earnings (5).

Also troubling is that new biotechnological advances in industrialized countries could result in synthetically produced replacements for some of Africa's most important export commodities (e.g., cocoa). This could have devastating consequences for some African economies. Synthetic substitutes for cotton and rubber, and especially jute and sisal, already have taken a heavy toll. These scenarios present issues that developed and developing countries alike need to address.

Finally, serious concerns exist regarding Africa's external debt problems. The combined debt of Sub-Saharan African countries pales in comparison to that of other developing regions, especially when compared to those of countries such as Brazil or Mexico. However, viewed as a percentage of gross domestic product or when considering what proportion debt servicing represents relative to total export earnings, the figures assume much greater dimensions. For example, Sub-Saharan Africa's ratio of debt to total exports is significantly higher than that of developing countries as a whole (10). Particularly alarming are figures that show precipitous declines in the financial flows to the region and a net outflow of income (10). It is hard to envision how African economies can maintain the status quo, let alone progress, under such conditions. Considerable attention is now being directed to the situation but many proposals have yet to be acted upon (17).

Box 2-1.—AIDS in Africa: Will It Affect Agricultural Development?

"Imagine the AIDS epidemic if the disease were well entrenched in the heterosexual population. If the Red Cross didn't screen the blood supply. If condoms weren't available. And if most hospitals couldn't test patients for the virus. Tragically, that's exactly the picture [some experts] paint of Africa today" (2).

World Health Organization (WHO) statistics as of June 1987 show that in Africa 27 countries have reported 4,570 cases of AIDS. But this figure is the tip of an iceberg, reflecting the continent's limited health infrastructure. WHO estimates that 20-35 percent of all patients in some hospitals have AIDS or AIDS-related diseases (7). Central Africa is the most severely affected, although adjacent countries in east and southern Africa are also caught in the epidemic. In an 11 nation strip from the Congo to Tanzania, an estimated 50,000 people have died from AIDS since the first confirmed appearance of the virus in the late 1970s. Up to 5 million people may be infected. Although estimates are somewhat uncertain, up to 99 percent of the people exposed to the virus can be expected to develop AIDS (15). This translates into several million deaths from existing infections alone (6,8).

Clinically, AIDS in Africa is no different than AIDS in developed countries: it is an invariably fatal disease, often characterized by a diarrhea-wasting syndrome, infections with organisms that normally do not cause disease, and cancer, such as Kaposi's sarcoma. In Africa, one local name for the disease is "slim disease," to describe the gaunt look of its victims. However, in Africa the male to female ratio of cases is 1:1. In developed countries, it is 13:1. In Africa the disease is transmitted predominantly by heterosexual activities, exposure to blood transfusions and unsterilized needles, and from mothers to newborns. Because sexual transmission is the dominant route of infection, the brunt of the illness is currently borne by people aged 20 to 49 (11).

It is impossible to predict the long-term economic and political impacts of the AIDS epidemic, or the impacts on agricultural development, but the selective involvement of so many young and middle-aged adults certainly opens the possibility for serious problems. One possibility in rural areas is that agricultural labor will shrink, and food production could suffer. As more of the economically productive members of society die, fewer resources will be provided for dependents such as young or very old people. This could create added burdens for governments and development assistance. In addition, Africa already lacks trained personnel in many fields, and AIDS could reduce the continent's capabilities even further as it strikes the blue- and white-collar work force (4). At a different level of impact, the disease could make personnel from development assistance organizations reluctant to work in Africa, harm tourism, and restrict training opportunities for Africans (3).

Impacts may also be felt on public policy both in Africa and in the nations providing development assistance. AIDS is an expensive disease: the costs of caring for 10 AIDS patients in the United States (approximately $450,000) is greater than the entire budget of a large hospital in Zaire, where up to 25 percent of the pediatric and adult hospital admissions are infected. The approximately $60 million spent in the United States on blood bank screening in 1985 is many times greater than the entire health budgets of many African countries (11). As the costs mount, African governments may focus their limited resources on fighting the disease, and less may be available to fund other priorities such as agricultural development. Similarly, donor assistance may increasingly be focused on AIDS, leaving less for other work.

The impacts of AIDS will reach into all aspects of African society and for now the prospects for controlling the disease are limited. However, 45 African countries have developed plans to fight the disease. These include establishing a national AIDS committee, conducting an epidemiologic assessment, and instituting a surveillance system for AIDS and AIDS-related infections. Education is given a critical role. But many countries lack the resources needed to build and sustain these activities on a long-term basis, so assistance is likely to be required.

TOWARD ENHANCING AFRICAN AGRICULTURE

The general nature of the above discussion masks considerable variation in severity of these problems among African countries, as well as their potential for dealing with them. It does, however, provide a backdrop against which the challenge of promoting agricultural development in the region should be viewed. The intent is not to create an impression of hopelessness but rather to provide a broad perspective to the challenges ahead for Africa and stress the need to address many fronts when pursuing African food security needs. African farming systems need to be a focal point of progress, but factors operating at the national and international levels also have strong influence.

The path toward improving food security will vary by country, by region, and even by household. Establishing blue-prints for how to meet food security needs is not realistic—diversity in Africa is too great, resources too variable, and objectives too personal. Africa will need assistance and support in meeting the challenges ahead. But solutions must come from within Africa because it is ultimately the onus of African governments, and more importantly the African people, to support the improvements in agricultural systems.

OTA's analysis indicates that success is more likely if development assistance builds off existing agricultural systems instead of replacing them. The track record of development agencies in assisting rural communities in Africa is poor. This suggests a need for greater caution when suggesting what development assistance can offer. Perhaps even more important is the need for a greater appreciation for existing practices. These practices are an important source of information and material for future improvements, not simply obstacles to "modern" agriculture. Further, a careful understanding of the precarious livelihood of low-resource agriculturalists is needed. This suggests an approach to development assistance that does not expose them to even greater risk, given the tenuous base for survival on which many function. Their practices and institutions are a direct response to reducing their vulnerability—and understanding these responses should be a prerequisite to interfering with them.

To help resource-poor farmers and herders thus requires an improved understanding of the environment in which these systems operate. To date, development assistance has overemphasized solutions from the outside—failing to account for local conditions, perceptions, and resources. Increased attention will have to be paid to soliciting input and support from the people that development assistance is supposed to help. In a sense, the development process in support of low-resource agriculture will need to shift from a monolog, in which communication is one-way from development agent to farmer, to more of a dialog, where communication and exchange of ideas operate in both directions. Enlisting these resource-poor farmers and herders as full partners in the development process enhances the chances that development efforts are directed to the right set of problems and that they will be adopted and sustained. Further, low-resource agriculturalists have an intimate understanding of such basic, but poorly documented, factors as local soil types, indigenous plants and animals, pest control, and climatic patterns. For development assistance groups to ignore this important local information is at best wasteful and at worst a recipe for failure.

In this assessment, OTA outlines approaches and technologies that show promise to help the African farmers and herders involved in low-resource agriculture. The goal is to provide options for Congress which, if pursued, can help African farmers, herders, and fishers enhance low-resource agriculture, increase their food security, and improve their lives.

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Part I:

Low-Resource Agriculture and Development Assistance

Chapter 3

The Status of Low-Resource Agriculture

CONTENTS

Page
Highlights 45
African Agriculture: Resourceful With Few Resources 45
  A Characterization of Low-Resource Agriculture in Africa 46
An Agroecological View of Low-Resource Food Production 50
  Arid and Semi-Arid Tropics 50
  Subhumid Tropical Uplands 53
  Humid Lowlands 53
  Tropical and Subtropical Highlands 56
Contributions of Low-Resource Agriculture to African Food Security 56
  Producing Most of Africa's Food 57
  The Primary Employer and Major Source of Income 58
  A Buffer Against Famine 59
Losing Ground: Concerns for African Agriculture 60
  Africa's Population Challenge for Agriculture 60
  Signs of Decline in African Agriculture 61
Obstacles To Improving Productivity and Food Security 64
  Biophysical and Socioeconomic Constraints 64
  Unsupportive Policies 66
  Infrastructural Weaknesses 67
  Underdeveloped Technical Institutions 68
Chapter 3 References 70

Boxes

Box *Page*
3-1. Terms Used in Describing African Agriculture 48
3-2. Profile: The Life of a Farmer 51
3-3. Profile: The Life of a Nomadic Herder 52
3-4. African Agroecological Zones and Primary Food Commodities 54

Figure

Figure *Page*
3-1. Women's Contributions to African Agriculture 49

Tables

Table *Page*
3-1. Importance of Agriculture to African Economies 46
3-2. Low-Resource Agriculture and African Staple Food Production 57
3-3. Summary of the Most Serious Environmental Degradation Problems by Region 63
3-4. Modern Input Use in Africa, Asia, and South America, 1977 68
3-5. Level of Support for Agricultural Research in Different Regions 69

Chapter 3

The Status of Low-Resource Agriculture

HIGHLIGHTS

- Low-resource agriculture is practiced by a diverse group of African farmers, herders, and fishers, is based primarily on the use of local resources, but may make modest use of external inputs, including information and technology.
- Low-resource agriculture predominates throughout Sub-Saharan Africa. It produces the majority of the region's food, involves and provides income for the majority of people, helps buffer against famine, and contributes to national economies by producing agricultural products for domestic use and export.
- Low-resource agriculture is no longer able to meet the needs of Africa's growing population. Declines in per capita food production and agricultural income, widespread malnutrition, and natural resource degradation are signs of its decreasing capability and reasons for concern about the future.
- Increasing numbers of Africans will depend on low-resource agriculture for food and livelihood in the coming decades. Thus, it is increasingly important to improve low-resource agricultural systems so they are better able to help meet Africa's food security and agricultural development needs.

AFRICAN AGRICULTURE: RESOURCEFUL WITH FEW RESOURCES

Africa's hallmark is its diversity. Its vast cultural diversity is manifest in nearly 800 distinct ethnic groups, which account for about one-third of the world's languages (23). The 45 countries of Sub-Saharan Africa show a wide array of political and economic systems, including numerous systems of tribal and modern law. The region also has wide ecological diversity—ranging from desert to savannah to rainforest—and broad soil and climate variations that can change over short distances. This diversity is mirrored in the nature of African agriculture. Having evolved under these differing biophysical and cultural influences, African agriculture encompasses a complex array of crop and livestock production systems.

Clearly, then, it is risky to generalize about African agriculture. There is no such thing as a "typical" African farm. Some common elements, however, can be identified. One consistent aspect of African agriculture is its prominent position in African economies (table 3-1). Agriculture employs about three-quarters of Sub-Saharan Africa's labor force and accounts for about one-third the region's gross domestic product. Also, about one-half of the countries in the region derive at least 40 percent of their export earnings from agricultural products. Further, despite major increases of food imports, particularly grains and dairy products, the region still produces most of its own food—at least 80 percent of its cereals, 95 percent of

Table 3-1.—Importance of Agriculture to African Economies

Country	Population in millions (1985)	Labor force in agriculture (% in 1980)	Agriculture as % of GDP[a] (1985)	Agricultural exports as % of total exports (1983)
Angola	8.8	74	(30-50)	(4)
Benin	4.0	70	48	(73)
Botswana	(1.1)	70	6(10-29)	(15)
Burkina Faso	7.9	87	45	(83)
Burundi	4.7	93	61	(98)
Cameroon	10.2	70	21(30-50)	(39)
Cape Verde	(0.3)	(52)	—	(19)
Central African Republic (CAR)	2.6	72	39	(51)
Chad	5.0	83	(30-50)	(63)
Comoros	(0.4)	(83)	(30-50)	(83)
Congo	1.9	62	8(10-29)	(1)
Djibouti	(0.3)	—	—	—
Equatorial Guinea	(0.4)	(66)	—	—
Ethiopia	42.3	80	44	(88)
Gabon	(1.1)	(75)	(<10)	—
Gambia	(0.6)	(84)	(10-29)	(54)
Ghana	12.7	56	41(>50)	(42)
Guinea	6.2	81	40	(9)
Guinea-Bissau	(0.8)	(82)	(30-50)	(43)
Ivory Coast	10.1	65	36	(59)
Kenya	20.4	81	31	(57)
Lesotho	1.5	86	(10-29)	(26)
Liberia	2.2	74	37	(18)
Madagascar	10.2	81	42	(87)
Malawi	7.0	83	38	(86)
Mali	7.5	86	50(10-29)	(77)
Mauritania	1.7	69	29	(14)
Mauritius	1.0	28	15	(57)
Mozambique	13.8	85	35	(18)
Niger	6.4	91	47	(21)
Nigeria	99.7	68	36	(4)
Principe and Sao Tome	(0.1)	—	—	(28)
Rwanda	6.0	93	45	—
Senegal	6.6	81	19	(29)
Seychelles	(0.1)	—	—	(9)
Sierra Leone	3.7	70	44(10-29)	(39)
Somalia	5.4	76	58	(93)
Sudan	21.9	71	26	(98)
Swaziland	(0.6)	(74)	(10-29)	(44)
Tanzania	22.2	86	58	(71)
Togo	3.0	73	30	(24)
Uganda	14.7	86	(>50)	(90)
Zaire	30.6	72	31	(36)
Zambia	6.7	73	14	(1)
Zimbabwe	8.4	73	13	(42)

[a] GDP = Gross Domestic Product

NOTES: Figures without parentheses are World Bank data, those in parentheses from FAO. FAO population data is for 1980. Where discrepancies in data were noted, both World Bank and FAO data are included.

SOURCES: World Bank, *World Development Report* (New York, NY: Oxford University Press, 1987); Food and Agriculture Organization of the United Nations (FAO), *Atlas of African Agriculture* (Rome: FAO, 1986).

its meat, 75 percent of its dairy products, and almost all roots and tubers (72). Although significant variations may exist from country to country or village to village, the overall importance of agriculture to African economies is indisputable.

A Characterization of Low-Resource Agriculture in Africa

Although it is difficult to generalize about African agriculture, a close look at the majority of the farming systems used shows that many share important attributes. Despite the great variation in approaches, most of Africa's agriculture can be categorized as **low-resource agriculture.** Low-resource agriculture is a form of agriculture conducted by a diverse group of poor farmers, herders, and fishers, based primarily on the use of local resources but may make modest use of external inputs, including information and technology. Local resources include the various renewable resources at hand, such as soil, water, and vegetation, etc., as well as local knowledge, labor, agricultural practices and management systems, and local institutions.

External resources refer to those agricultural inputs and technologies (e.g., commercial fertilizer and pesticides, hybrid seeds, tractors, and irrigation systems) and information (e.g., management skills and data) that originate outside the local area and typically depend on continued external support. These external resources are commonly referred to as "modern" inputs because of how they have changed agriculture over the last 50 years, especially in developed countries. The distinction between local and external resources sometimes is not clear. Resources that came from outside of the local area in the past now may be considered "local" because of adaptation and a long history of use. For example, most of Africa's staple crops (e.g., corn) were introduced from outside the continent but have since evolved unique varieties in various regions.

A Continuum of Resource Use

The definition of low-resource agriculture is a conceptual one that is difficult to quantify, in part because the available aggregate data on African agricultural production do not distinguish the degree of modern input use, only whether or not farmers use them (64).

Resource use in African agriculture is best viewed along a continuum, acknowledging that various kinds of inputs and outputs can change over time or according to what is being raised. African agricultural systems range from small- to large-scale, from using no modern inputs to using many modern inputs, from producing crops and livestock for subsistence to producing them for sale, and from providing low incomes to providing high incomes. However, the vast majority of Africa's farmers, herders, and fishers operate on the lower to middle end of this range and these people are the focus of this report.

The agriculturalists working on the lowest end of the resource use scale are relatively easy to identify: they use no modern inputs, earn little money, and produce goods primarily for their own family's consumption. These people are sometimes referred to as subsistence agriculturalists or low-input farmers (box 3-1). It is possible to estimate roughly how much food this subset of low-resource agriculture produces, which helps establish an idea of the contribution made by these "low-end" low-resource agriculturalists. These estimates are discussed later in this chapter.

Moving up along the resource use continuum, the importance of external inputs increases; farmers may use small amounts of fertilizer and improved crop varieties and herders may have some access to veterinary services. The level of modern input use can vary among farms and herds and even on the same farm between crops and seasons. For example, a low-resource farm in Senegal may grow an improved rice variety using irrigation and low levels of fertilizer as well as an intercrop of local varieties of maize and cowpeas that receives no fertilizer or pesticides.

On the highest end of the resource use continuum are the relatively few high-resource African farms. These include large-scale, privately owned commercial operations (e.g., plantations); large mechanized state-run farms; and large-scale cattle ranches. These agricultural systems rely on greater amounts of inputs, including information and technology and developed support services such as transportation infrastructures, established markets, and input supply. The contribution of these large-scale farms to Africa's food production probably is no more than about 5 percent (47). These operations are not examined in this report.

Box 3-1.—Terms Used in Describing African Agriculture

OTA's use of the term low-resource agriculture is not intended to coin a new phrase or suggest a radically different view of African agriculture. Instead, "low-resource agriculture" is used to emphasize the strong dependence of farmers, herders, and fishers on resources internal to agricultural systems, their poverty, and the existence of combined farming, herding, and fishing practices. Each of these is a defining feature of most African agriculture but not well captured in other terms. While the term low-resource stresses limited resource use, it does not mean *no* use of external inputs (i.e., "no-resource"). Input use varies among low-resource producers and within their operations.

These points are emphasized to varying degrees in related terms used by the development assistance community, including:

- *Low-input agriculture*: As used by FAO, the primary input in these systems is hand labor. No modern inputs (e.g., fertilizer and herbicides) or technologies (e.g., soil conservation techniques) are used (67). This definition is narrower than that of low-resource agriculture because low-input agriculture includes only those systems at the lowest end of the input continuum where no modern, or external, inputs are available.
- *Smallholding/small farm*: These terms are used frequently to describe African agriculture. They overlap considerably with low-resource agriculture, but differ in two respects: this definition connotes small farm size, a description which is inadequate when talking about pastoralists who use very large areas. Also, the *level* of external inputs used on small farms is not explicit in the definition. In some cases, smallholders may use high levels of external inputs. For example, smallholders in Kenya's highlands have established a dairy based on crossbred cows, including artificial insemination, input and extension services, and a marketing network. This operation would not be included in OTA's definition of low-resource agriculture because resource-poor farmers use fewer external inputs, regardless of farm size.
- *Subsistence farm*: Subsistence farms generally gear their production to meeting household needs. By most definitions, no more than 50 percent of the output is sold. While the precise proportion of sales is debatable, the low participation of producers in commercial markets and in cash cropping is the rule. "Subsistence" farms would exist at the lowest end of a resource use continuum. Low-resource agriculture is broader—focusing on food production and rural purchasing power as integrated components of food security.

Some high-input, highly commercialized, but small-scale operations also exist in Africa. These enterprises generally operate in more climatically favorable regions within a select number of countries, tend to be well integrated into national economies, and have good access to national and export markets. Examples include certain smallholder operations heavily geared to export commodities (e.g., coffee and cocoa) that account for a high proportion of Africa's fertilizer and pesticide use. Smallholder commercial dairy operations, such as those in parts of Kenya that rely heavily on input and output markets, might also be included in this category. Although this category provides some insights about how to enhance low-resource agriculture and may benefit from the sorts of technologies outlined in this report, the main focus of discussion here is on farmers and herders at a lower portion of the resource continuum.

Describing Low-Resource Agriculture

Low-resource agricultural systems are typically complex, diversified, and changing, but they generally share certain characteristics:

- they strive to reduce risk, even if this means obtaining less than maximum yields;
- they depend on local knowledge;
- they depend on biological processes and renewable resources;
- they involve low cash costs, but relatively high labor costs and low labor productivity; and
- they are adapted to local cultures and envi-

ronments, although social and ecological systems are showing increasing strains under growing pressures.

The resource-poor agriculturalists who use these systems generally are poor and have limited access to and control over land, water, labor, capital, external sources of information and technology, and external inputs such as commercial fertilizer. Raising food, including livestock, is a major production activity but they may also engage in cash-crop production, fishing or fish-farming, forestry, food processing and marketing, and a host of other income-generating activities.

The range of activities and how they are performed is a response to this group's great vulnerability to factors outside their control. Activities of resource-poor agriculturalists reflect a need to reduce the risks created by fluctuations in climate, the economy, and the political system. This tends to result in lower than optimal yields, but with the benefit of producing household food supplies throughout as much of the year as possible. This strategy has been characterized as a kind of "adaptive diversity" that, while not providing maximal returns under optimal conditions, is able to provide reasonable returns under a wide range of fluctuating and unpredictable environmental conditions (43).

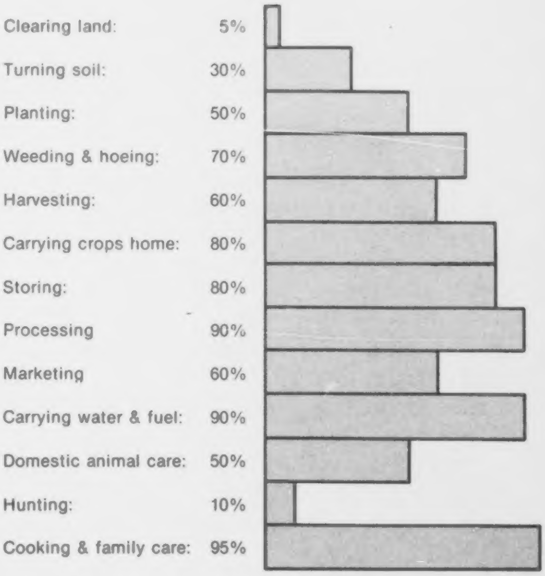
Poverty seriously constrains most farmers from investing in agricultural improvements. It is not unusual for a farmer's total annual capital investment to be under $10 (9,42). Expenditures in the semi-arid tropics of West Africa, where labor commonly is hired, may reach $20 to $60 per hectare (42). Although expenditures other than labor appear to be small, in many cases they represent a high proportion of the capital actually available to a household for expenditures other than food (52).

In low-resource agriculture, the family or household provides the critical source of labor. The division of labor in African agriculture varies across the continent. Men are primarily responsible for land preparation and planting in many areas, whereas women are primarily responsible for weeding and harvesting. In other areas, men are responsible for producing export crops, whereas women work in the production of the export crops as well as in separate fields to produce food for household consumption.

Data from most African countries confirm that women play a major role in agriculture, especially in women-headed households (figure 3-1). Women contribute about two-thirds of all hours spent producing food in traditional agriculture, about 70 percent of the hours devoted to marketing, and at least 80 percent of the hours spent on food processing and storage (31). The elderly and young children of the household also make significant contributions to agricultural production, from scaring birds and harvesting crops to tending small livestock.

The dependence on household labor can lead to seasonal labor shortages as well as periods of underemployment. The need for manual labor is especially high during seasonal activities such as land clearing, tilling, sowing, weeding, and harvesting. These periods represent

Figure 3-1.—Women's Contributions to African Agriculture



SOURCE: U.N. Economic Commission for Africa, *Women in Africa*, 1975.

peaks in labor demand and available household labor may be inadequate. The ability to meet this peak demand has been further constrained as many young men seeking jobs migrate from rural to urban areas or to distant rural regions for commercial jobs such as those on agricultural estates or in mines. On the other hand, however, seasonal underemployment occurs during times when little agricultural labor is needed, especially in the shorter growing season, semi-arid regions (50).

Low-resource agriculture thus can be seen as a livelihood meeting multiple needs, and it involves balancing scarce endowments of land, labor, and capital. For the farmer or herder, this involves a complex decisionmaking process that regularly requires difficult trade-offs. This complexity also creates challenges for researchers trying to decipher the process. Analyses that focus narrowly on only one particular activity in low-resource systems can lead to misguided or inappropriate conclusions about how to improve that activity since the assistance may be inconsistent with the overall household production system. For example, new technologies that require increased labor, particularly during peak labor periods, may not be feasible for a farming household to adopt if it means drawing someone's time away from other important activities.

Although low-resource agriculture was once perceived as inefficient and somewhat haphazard, recent investigations have given rise to a far greater appreciation of the efficiency and logic of various systems and practices—given families' available resources and multiple objectives. Further discussion of the features of low-resource agriculture and their implications for development assistance is provided in chapter 4. Boxes 3-2 and 3-3 illustrate two particular low-resource systems.

AN AGROECOLOGICAL VIEW OF LOW-RESOURCE FOOD PRODUCTION

Socio-economic factors are extremely important in defining the nature of low-resource agriculture. It is also essential, however, to evaluate how agroecological factors help define production in low-resource agricultural systems. The discussion that follows is organized around four broad agroecological zones (box 3-4). This organization provides an overview of African agriculture and is a simple way to address various management and development assistance issues. Reality, however, is rarely simple. Each zone on the map includes a wide range of agroecological conditions that reflect heterogeneity at the microlevel. Each zone is likely to produce some of each particular crop and kind of livestock and multiple crop and livestock varieties tend to be raised together. Home gardens are important in all zones, for example. Defining only the major food crop also masks the importance of the cash crops grown, as well as the importance of the many non-farm activities pursued by low-resource agriculturalists. Thus, the following regional sketches and the summaries in box 3-4 are intended simply to illustrate the relative importance of major crops and livestock in each zone.

Arid and Semi-Arid Tropics

Millet is the predominant crop in Africa's drier areas, where it is commonly the only cereal that can be grown under rainfed conditions. Sorghum replaces millet as the principal crop in wetter areas or on more moisture-retaining soils. Maize, which is less drought tolerant than either of the other two cereals, is produced to a small extent in this zone. Whether grown separately or intercropped, millet and sorghum are typically grown under low-resource conditions using local varieties and little or no fertilizer or pesticides (1,42,48,75) (app. D). Rice is an important crop but its production is restricted to river basins. Although some improved varieties are used, less than 5

Box 3-2.—Profile: The Life of a Farmer*

Malawi is a landlocked country in southern Africa, bordered by Tanzania, Zambia, and Mozambique. At least 80 percent of the people in Malawi are rural and make their livings farming. In the center of the country is a broad plateau called the Lilongwe Plain—an area of good soils and adequate rainfall that is the granary for the country. It is here that Sindima lives on a farm of about 2½ hectares that includes land she inherited from her mother and land that belongs to her husband.

Sindima is in her late thirties and has five living children; two other children have died, and it's likely that she will have two or three more children in time. She is head of her household—which is not unusual in Malawi, where at least one-third of all rural households are headed by women. Sindima's husband moved to Lilongwe, the capital, to find work. It takes 2 days for him to walk home, so she sees him infrequently. This means the traditional division of labor on their farm has shifted—in their grandparents' time, the men did all the heavy work, like clearing new land, plowing, or building fences, and the women did all the planting, weeding, harvesting, and processing. In her family, decisionmaking was shared. Now, however, Sindima makes almost all the management decisions, and she and her children do all the work. Since most of the land is under continuous cultivation, there is little opportunity to clear new lands, which is one of the reasons her husband felt compelled to leave for the city.

By local standards, Sindima is affluent. Because she and her husband belong to a local farmers club, she has access to the extension agent for information. A development assistance project supplies credit in the form of some fertilizer and improved seeds, which she will pay back when she sells the crops after the harvest. With this help, she plants a more complicated mix of crops than many of her neighbors—hybrid and local maize, groundnuts, beans, a variety of local vegetables, and a little tobacco. She uses the fertilizer and improved maize on about one-half hectare, but she continues to plant local maize even though it is less productive because it tastes better and is less susceptible to insect damage in storage.

Sindima is quite knowledgeable about managing her fields, particularly the garden crops she grows near the house. Because she has a relatively good size farm, Sindima is able to grow some maize and tobacco as monocrops, which simplifies the labor and management required. Like most of her neighbors, however, most of her land is intercropped and she has a sophisticated understanding of crop rotation, planting times, weeding requirements, and allocation of labor. Sindima knows it is important not to overwork the land. But it's more difficult now than ever to let a field lie fallow to regain fertility because of the pressure she feels to produce the most she can from her small farm.

In the past, Sindima took some extension classes on nutrition and sewing, but only recently have they let women take the farming courses. She hopes to take a course about using the improved maize varieties soon, because she has been learning by trial and error so far. Of course, finding time for classes is hard when she almost always has something to do in the fields or her household. Just grinding maize enough for her own family takes hours; so does finding enough firewood. She keeps some chickens and goats, too, which have always been the woman's responsibility. Her children help with many tasks—the two older girls walk to the community well twice each day to get water, and everyone helps with harvest—but she wants them to stay in school. With the money she makes at market (she not only sells crops, but also a little tobacco and home-brewed beer) and the money her husband sends, she can pay their school fees and sees education as a high priority.

Sindima illustrates what can be accomplished on a small farm with few resources—but she has an advantage over many other women who farm alone. After all, she has a husband sending money, two parcels of land, and access to the agricultural extension system. Her cousin Nanthalo, on the other hand, is younger, divorced, with three small children. To make ends meet, she hires out to help others with planting and weeding, but this interferes with the time she has to devote to her own fields. (Since this is a matrilineal society, she kept her land when her husband left; in many other countries, she would be worse off because all land belongs to the men.) She does not have the money to keep her children in school, and her child care responsibilities keep her from taking any extension classes. With only one small parcel of land, her farm is too small to be eligible for credit packages or other help from extension. She gets by as she can, and depends on help from relatives like Sindima. While Sindima illustrates the potential of low-resource farming styles in Malawi, Nanthalo may well be more typical.

*Sindima is fictional but this profile is a composite drawn from the lives of real people.

SOURCES: Anita Spring, Associate Dean, College of Liberal Arts and Sciences, University of Florida, Gainesville, FL, personal communication, 1987, and "Profiles of Men and Women Smallholder Farmers in the Lilongwe Rural Development Project, Malawi," report to Office of Women in Development, U.S. Agency for International Development, Washington, DC, March 1984.

Box 3-3.—Profile: The Life of a Nomadic Herder[*]

The Sahel region of West Africa is vast and dry, a seemingly inhospitable land. Yet for 6,000 years, nomadic herders have made productive use of what is, to many, a marginal environment. They have learned to use the ecosystem to their advantage, moving when they must seek water and forage to satisfy their livestock.

Mossa is a herder, like his father and his father's father. He is in his forties, the youngest of nine children, and has lived his life in an area north of Timbuktu, Mali. He and his wife have three sons and four daughters still alive; four other children have died. Mossa's life is typical of that found in this large expanse of arid and semiarid land, although from a broader perspective he illustrates only the lifestyle of the 6 percent of Africa's population that is nomadic.

Animals are the core of life for Mossa and his family. Cattle, sheep, and goats provide milk, butter, cheese and, for special occasions, meat. The heavy tents Mossa and his family live in—strong enough to withstand high winds, sand storms, and the driving rain of the wet season—are made of hides, as are their sandals and many household goods. When the family needs grain or other goods, Mossa sells or trades what he must from the herd. His herd size is respectable by local standards; he has some cows, calves, and heifers, plus a number of goats and some sheep. Mossa, his father, and others before them have carefully applied their knowledge and management skills to these animals and their breeding. And while Western veterinary medicine is not generally available, he has a variety of traditional, and often effective, methods for treating his animals.

The herd represents more than a source of income to Mossa and his family. It is a measure of their wealth, status, and security. This is not merely a matter of pride: livestock are their "bank account," their way of saving resources for bad times in a land that has unpredictable but frequent droughts.

Mossa's nomadic community consists of about 10 related families who move together with their livestock following good pasture and water. During the dry season, they break camp before dawn and travel before the heat of noon. They camp near a particular well as long as the pasture holds out—usually a matter of a few weeks. During the wet season, they move more frequently to take advantage of the better forage. They must always camp within about 10 km of water because their small livestock must be watered every day.

Life is changing rapidly for Mossa now. He has far more contact with urban people than his father did, and this has changed his and his family's expectations. They buy more household goods and eat some different foods. Young men from the community are far more likely to leave now and go to the city in search of work, which changes the family structure for those that remain. Mossa's ability to make a living from the land is changing too. Some productive lands he once grazed have deteriorated, like the area around the government-dug deep well. It was a good idea gone awry: water is always needed, but too many animals concentrated around one water source stripped the land of its vegetation, starting in motion a chain of erosion and degradation. In other places, crop farmers have taken over land where he and his family once grazed their livestock. In particular, one area he traditionally used during dry periods has become part of a large landholding owned by an absentee civil servant, and he can no longer go there. His risk has increased: during the next severe drought, Mossa will probably lose a large part of the herd. Mossa still has yet to recover from the last drought when, like most other herders, he lost half his animals.

During this recent drought, for the first time Mossa was unable to feed his family. International assistance organizations provided food aid to Mossa's community, but little else. Indeed, Mossa sees fewer donor-supported livestock projects than he did a decade ago, and he wonders whether his own government or any of the many other groups that attempt to help really know how to help him improve his life.

[*] Mossa is fictional but this profile is a composite drawn from the lives of real people.

SOURCES: American Friends Service Committee (AFSC), *Tin Aicha Nomad Village* (Philadelphia, PA: AFSC, 1982); Michael M. Horowitz, *The Sociology of Pastoralism and African Livestock Projects*, AID Program Evolution Discussion Paper No. 6. (Washington, DC: Bureau for Program and Policy Coordination, AID, May 1979); George S. Scharffenberger, Consultant, Washington, DC, personal communication, 1987.

percent of the rice production in Africa consists of High Yielding Varieties, unlike most other parts of the world where these are used extensively (13).

Food legumes, especially cowpeas, are often intercropped with cereals under low-resource conditions. Root and tuber crops are less important in the arid and semi-arid zone than in others, but they provide a small percentage of the dietary energy supply (72).

About 60 percent of tropical Africa's ruminant livestock and virtually all of the continent's estimated 11 million camel live in the arid and semi-arid zone (30,60). The region is characterized by a low livestock/land ratio, but a high livestock/human ratio. Pastoralist systems of various kinds prevail. For example, nomadic systems, which occupy the drier regions of the Sahel that are unsuitable for crop production (i.e., rainfall less than 300 mm/yr), use nutrient-rich natural vegetation produced during the short rainy season. These people then move south during the dry season. Transhumant pastoralists—those who are mobile around a fixed base—are most common in the semi-arid zone receiving 300 to 600 mm/yr of rainfall. Sedentary agropastoralists—those who remain in one place—have become increasingly common in more favorable areas within this zone. An estimated 40 percent of Sahelian cattle and even larger percentages of small ruminants are being raised under this system (82).

Virtually all of the rangeland livestock production in the arid and semi-arid zone can be considered low-resource agriculture. In Sudan, for example, an estimated 90 percent of livestock is produced with virtually no outside inputs (app. D, 75). The exceptions are ranching activities that are important in a few southern African countries, such as Botswana and Zimbabwe. Overall, however, ranching activities in Sub-Saharan Africa probably account for only about 6 percent of Africa's livestock production (7).

Subhumid Tropical Uplands

Sorghum and maize are the predominant cereals in Africa's subhumid tropical uplands. In this zone, sorghum is the preferred cereal for drier conditions and whereas maize is more common in wetter areas. Maize commonly receives some modern inputs. Compared to millet and sorghum, it is not clear how much of the maize production should actually be considered "low-resource." For example, in the leading maize-producing countries—Zimbabwe and Kenya—most land is planted with hybrids (15). Yet most countries across all agroecological zones report low national productivity averages (e.g., Ivory Coast: 660 kg/ha, Zaire: 780 kg/ha, Angola: 510 kg/ha—compared to 1,940 kg/ha average in Zimbabwe) (72), an indication that most maize is produced under low-resource conditions.

Roots, tubers, and plantains are also prevalent in subhumid areas, although less so here than in the humid lowlands. As in the arid and semi-arid zone, food legumes and rice are also produced.

N'Dama and Zebu cattle are the most economically important livestock in the subhumid zone, followed by goats and sheep (30). Grazing densities are low, on par with the arid zone and less than one-quarter of that in the highland regions. Low productivity is the result of nutritionally deficient forage (i.e., inadequate protein and minerals), despite the generally favorable quantity of forage growth (28). Also trypanosomiasis prohibits livestock production in about two-thirds of the subhumid zone (63).

Livestock and crop production are not well integrated in mixed farming systems, although close links often exist between pastoralists and farmers, especially in West Africa. Examples of links include exchanges of food crops for livestock products, exchanges of post-harvest fodder for organic fertilizer (manure), and reciprocal labor arrangements (40). Increasingly, however, these complementary relationships seem to be overshadowed by competition for land and resources (40).

Humid Lowlands

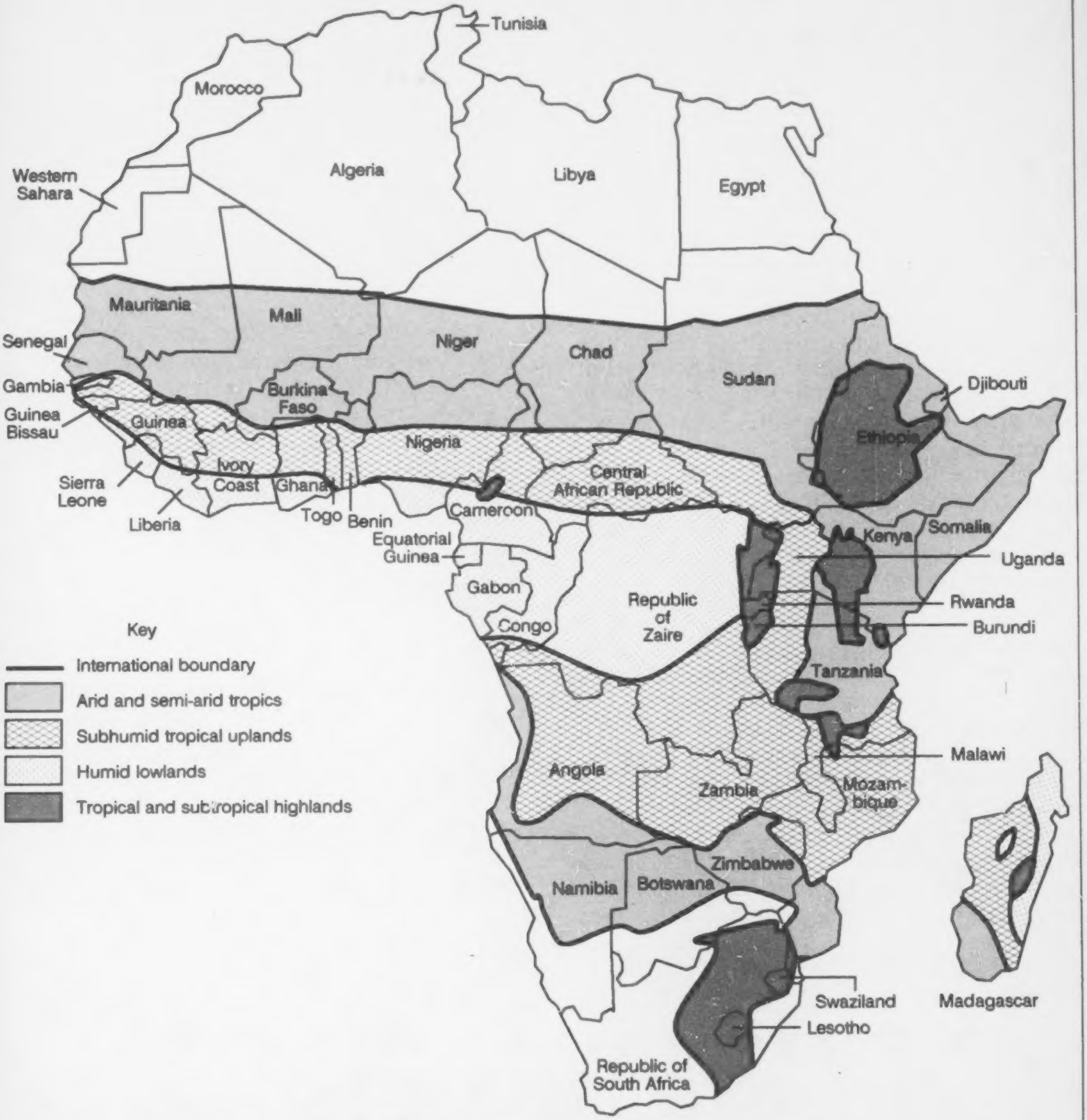
Roots, tubers (e.g., cassava, yams, sweet potatoes, and cocoyams), and plantains are the predominant crops and major sources of calories

Box 3-4.—African Agroecological Zones and Primary Food Commodities

Agroecological zone	Length of growing period[a] (days)	Annual rainfall	Primary food commodities
Arid and Semi-Arid Tropics	1-74 (arid) 75-180 (semi-arid)	100-1,000 mm	Little cultivation in arid areas. Millet and sorghum predominant, with millet grown in drier areas. Maize in wetter areas and rice in river basins. Food legumes (e.g., cowpeas and groundnuts) important and some roots and tubers grown in wetter areas. Approximately 60% of Africa's ruminant livestock (goats, sheep, cattle, and camels) raised here by both nomadic and settled pastoralists.
Subhumid Tropical Uplands	180-270	900-1,500 mm Bimodal rainfall in East Africa	Sorghum and maize are the most important cereals, with sorghum preferred in drier areas. Roots, tubers, and plantains are important. Food legumes and rice also produced. Two-thirds of the zone are affected by trypanosomiasis (spread by the tsetse fly) which inhibits livestock production. N'Dama and Zebu cattle are the economically most important livestock followed by goats and sheep.
Humid Lowlands	270+	1,500+ mm Bimodal rainfall	Roots, tubers, and plantains predominate (e.g., cassava, yams, etc.) Some maize, rice, and sorghum. Trypanosomiasis exists throughout the zone precluding almost all but the small trypano-tolerant N'Dama cattle and tolerant goats and sheep. Some poultry and swine production.
Tropical and Subtropical Highlands	Variable	Variable	Mixed farming (livestock and crops raised on same farm) prevails. Predominant cereals are maize and sorghum. Roots and tubers (especially sweet potatoes) are important in specific countries. Plantains and food legumes are also grown. The absence of trypanosomiasis and availability of good fodder allow a stocking density four times the average.

[a] Length of growing period is the period when both moisture and temperature permit crop growth.

SOURCES: U.S. Agency for International Development, Bureau for Africa, *Plan for Supporting Natural Resources Management in Sub-Seharan Africa*, (Washington, DC: USAID, February 1986). Food and Agriculture Organization of the United Nations, *African Agriculture: The Next 25 Years: Atlas of African Africulture* (Rome, FAO: 1986). International Livestock Center for Africa, *ILCA Annual Report 1983* (Addis Ababa, Ethiopia: ILCA, 1984).


Tunisia
Morocco
Algeria
Libya
Egypt
Western Sahara
Mauritania
Mali
Niger
Chad
Sudan
Senegal
Gambia
Guinea Bissau
Guinea
Burkina Faso
Nigeria
Ethiopia
Djibouti
Sierra Leone
Liberia
Ivory Coast
Ghana
Togo
Benin
Cameroon
Central African Republic
Equatorial Guinea
Gabon
Congo
Republic of Zaire
Kenya
Somalia
Uganda
Rwanda
Burundi
Tanzania
Malawi
Angola
Zambia
Mozambique
Zimbabwe
Namibia
Botswana
Swaziland
Lesotho
Madagascar
Republic of South Africa
Key
International boundary
Arid and semi-arid tropics
Subhumid tropical uplands
Humid lowlands
Tropical and subtropical highlands

SOURCES: Adapted from U.S. Agency for International Development, *Plan for Supporting Natural Resources Management in Sub-Saharan Africa*, (Washington, D.C.: USAID, February 1987). Zonation for Madagascar from U.N. Food and Agriculture Organization (FAO), *African Agriculture: The Next 25 Years—Atlas of African Agriculture* (Rome: FAO, 1986); International Livestock Center for Africa (ILCA), *ILCA Annual Report 1983* (Addis Ababa, Ethiopia: ILCA, 1983).

throughout the humid lowlands (72). These are grown almost completely under low-resource conditions (27,74,75) (app. D). While most of these crops can be grown under widely ranging rainfall and soil conditions and therefore are produced in all agroecological zones, cocoyams are restricted to the humid lowlands (25). Maize, rice, and sorghum are grown in various parts of this zone, as are a wide range of food legumes and vegetables.

Although the humid zone comprises almost 20 percent of Sub-Saharan Africa, it accounts for only about 7 percent of the ruminant livestock production. Virtually the entire humid zone is infested with tsetse fly, precluding almost all but the small trypano-tolerant N'Dama breeds of cattle. Goats and sheep, which are more tolerant of trypanosomiasis, assume greater importance in this zone, although other diseases (e.g., Peste de Petit Ruminant) and parasites can restrict their production. However, women manage a few small ruminants in most areas in conjunction with their home gardens.

Poultry and swine production are of particular importance in the humid zone, particularly near population centers. Swine production, restricted in many areas because of disease and religious taboos, is most common in humid coastal regions. Rapidly increasing demand for poultry, and to a lesser extent swine, has promoted intensification in traditional production systems. A significant share of these production increases are possible because of imported large-scale commercial production technology being developed near urban centers (82).

Tropical and Subtropical Highlands

Even though the highlands contain no more than 5 percent of Africa's land area, generally favorable agroclimatic factors enable it to support nearly 20 percent of the region's rural population. The zone produces a wide range of crops. Cereals, primarily maize and sorghum, predominate in most countries. However, root and tuber crops, especially sweet potatoes, are more important in such countries as Rwanda and Burundi (72). Plantains and food legumes also contribute to the diet.

Livestock production, especially cattle, is an important activity, with almost 20 percent of Africa's ruminant livestock production occurring in the highlands (22). Generally fertile soils, moderate temperatures, and ample rainfall result in relatively high fodder production. These factors, combined with the absence of trypanosomiasis and the use of high-yield imported breeds and cross-breeds, allow a stocking density almost four times the average for Africa.

Most farming in the highlands, consists of mixed systems where crops and livestock are raised in the same management units (22). This is the only zone where such integration is well developed. High human population densities, relatively well-established distribution systems, and numerous markets have led to progressively greater use of purchased inputs. In the most favorable highland regions, many small-scale farmers have established highly commercialized operations, using predominantly high-yielding crop varieties and modern inputs such as artificial insemination services for livestock.

CONTRIBUTIONS OF LOW-RESOURCE AGRICULTURE TO AFRICAN FOOD SECURITY

Low-resource agriculture makes a crucial contribution to African food security[1] because it is significant to household food production and income generation. Low-resource agriculture is the source of most of Africa's food, a primary income and employment source for the majority of Africans and African governments, and a strategy used by many of Africa's most vulnerable people to buffer themselves against food shortfalls and famine.

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[1] Food security can be defined as access by all people at all times to enough food for an active, health life; food security depends on both the availability of food and the ability to acquire it (79).

Producing Most of Africa's Food

The majority of food production across Africa, is by low-resource agriculture. Low-resource agriculture produces the majority of grain, except wheat and perhaps maize. Almost all root, tuber, and plantain crops, and the majority of food legumes are produced on low-resource farms (table 3-2). In addition, a great variety of secondary crops such as fruits and vegetables are grown under low-resource conditions to supplement these staples (app. D, 75).

An estimated 75 percent of all livestock in Sub-Saharan Africa is raised on farms where crop production is the principle source of subsistence, and livestock are an important source of cash income. Most of these livestock receive little supplementary feed or health care (7) and their production can be considered "low-resource." Approximately 20 percent of live-

Table 3-2.—Low-Resource Agriculture and African Staple Food Production[a]

Crop/livestock/fish	External input use[b]	Minimum estimate of low-resource production[c]
Millet	Virtually no use of fertilizers and very little use of improved seed.	72%
Sorghum	Basically the same situation as millet, but hybrids and commercial inputs are becoming more important in some areas.	61%
Maize	At least 75 percent produced without hybrid seeds and with less than recommended fertilizer levels; but probably as much as two-thirds produced with non-hybrid improved seed and moderate levels of fertilizer.	37%
Rice	At least 75 percent produced using less than recommended levels of fertilizer and receiving inadequate irrigation (and no more than 5 percent using High-Yielding Varieties).	76%
Food legumes (e.g., cowpeas, pigeon peas, beans, and groundnuts)	Most crops of this diverse group receive virtually no commercial inputs, but some production is under higher-resource conditions (e.g., up to 50 percent of groundnut production).	55% groundnuts 49% beans
Roots, tubers, and plaintain (e.g., cassava, yam, cocoyam, and sweet potato)	Virtually no use of fertilizers or improved seed. Some high-resource banana production for exports.	93% cassava 100% yams 100% cocoyam
Cattle	Six percent produced on ranches, generally considered high-resource; 20 percent produced by pastoralists, virtually all under low-resource conditions except for occasional veterinary care; 74 percent produced in mixed farms, a minority of this under higher-resource conditions, such as dairy farming in some highland areas.	
Small ruminants and other livestock (e.g., sheep, goats, poultry, and swine)	Almost all sheep, goats, and camels raised under low-resource conditions; most swine and poultry produced under low-resource conditions, but increasingly more produced under higher-resource conditions, especially near some urban areas.	
Fish	As much as 85 to 95 percent caught in small-scale artisanal fisheries mostly under low-resource conditions, though increasingly fishers are using outboard motors; the remainder is harvested by large-scale offshore operations mainly by foreign-owned vessels.	

[a] Aggregate agricultural data for Africa usually do not detail levels of external input use but only whether or not such inputs are used. Table 3-2 shows the importance of low-resource production in two ways. First, it describes the type of input use for the production of specific commodities and second, it sets a minimum boundary on the volume of low-resource production of specific crops, based on estimates on "low-input agriculture" production in eight African countries.

[b] Column 2 provides descriptions of the types and levels of external inputs used for specific products. These descriptions help to locate where the majority of production takes place along the range of modern input use. The descriptions were compiled from a set of technology papers written for OTA (app. A) and additional outside publications.

[c] Column 3 represents an effort to establish quantitative estimates of the minimum contributions of low-resource agriculture. The data show production under conditions of no modern input use for eight sample countries. These eight countries account for at least 50 percent of African production of maize, sorghum, millet, cocoyam; and no less than 30 percent of cassava, groundnut, and rice production. The data were compiled by the Economic Research Service of the U.S. Department of Agriculture for OTA. (See app. E)

SOURCE: Office of Technology Assessment, 1988.

stock production occurs in pastoral systems, where animals are the major source of income and food (milk is often more important than meat) (63). Pastoralist systems, by their nature, are low-resource enterprises, although some use of veterinary services is becoming more common. Just over 5 percent of Africa's livestock is raised on higher resource ranches (7).

Fish are a principal source of animal protein in many parts of Sub-Saharan Africa (17). An estimated 85 to 95 percent of African fish harvest is from traditional artesanal fisheries—small-scale operations that do not use expensive equipment or inputs (44,53) and fall within a definition of low-resource agriculture.

The Primary Employer and Major Source of Income

An estimated three-quarters of Africa's labor force are involved in agriculture, and a large majority of these workers are engaged in low-resource farming and herding. For them, farming and herding systems represent their primary source of income as well as food. The sale of food and other agricultural products accounts for between 60 and 80 percent of the income of most rural producers in Africa (21, 24). Other non-farm activities also represent important sources of income but are most often pursued in conjunction with, rather than in place of, on-farm activities.

Low-resource agriculture is of particular importance for African women, who constitute the major food producers in most African countries and account for about one-half the agricultural labor force (3). Women also earn a significant portion of household agricultural income because of their predominant role in marketing activities—selling agricultural products (e.g., peanuts, vegetables, or grain) and generating income from processing activities (e.g., cheese, beer, or soap-making). The role of women as farm managers is also growing in importance. Although women typically engage in some autonomous activities within male-headed farming households (e.g., managing separate fields), the number of female-headed households is increasing as growing numbers of men seek work away from the farm.

Low-resource agriculture contributes to national as well as household income. Agriculture's share of the gross domestic product of African nations averaged approximately 41 percent between 1982 and 1984 (81). In addition, agricultural production contributed significantly to the export earnings of many countries. Agricultural exports in 18 countries, provided at least 50 percent of the value of total exports in 1983. In another 12 countries, they provided at least 20 percent (72).

The exact contribution of low-resource agriculture to exports is difficult to estimate. Data show that low-resource agriculturalists produce more food crops than cash or export crops such

Photo credit: U.S. Agency for International Development

Low-resource agriculture provides income for a large proportion of Africans. Women play a large and growing role in the continent's farming systems.

as coffee, cocoa, cotton, and rubber (app. D, 75). The latter crops tend to receive the highest input levels, and in this sense are less likely to be considered low-resource. However, there are important links between the production of these exports and food crops.

A sizable proportion of export crops, perhaps even a majority, are produced by small farmers who are also producing food crops under low-resource conditions. USDA data show, for example, that in Kenya 64 percent of coffee exports, 40 percent of tea exports, and nearly 100 percent of cotton exports are produced by smallholders. Even in Malawi, with its large tea, sugar, and tobacco estates, smallholders accounted for an estimated 64 percent of the value of agricultural exports in 1979/80 (64). If local markets cannot provide a dependable food supply for these farmers, they will devote more of their resources to growing food, thereby constraining their export crop production and consequently reducing national exports (64). The result can be a decline in foreign exchange earnings and fewer resources for governments to devote to economic development, including the agricultural sector. In turn, the use of modern inputs and other investments in agricultural improvements, made affordable by growing cash or export crops, can have a direct or residual benefit on food crop production. For example, fertilizer remaining in the soil after its application for a cotton crop benefits the subsequent, unfertilized, rotation of millet (64).

A Buffer Against Famine

Resource-poor agriculturalists commonly face periods of inadequate food availability. Seasonal shortfalls can occur annually when food from past harvests is exhausted but before new crops can be harvested. For herders, inadequate access to suitable dry-season fodder generally results in shortfalls in milk production, the major source of nutrition for pastoralists. These seasonal shortages are sometimes called the "hungry period." Famine, on the other hand, is a more extreme incidence of food shortfall with no set period.

The practices of resource-poor farmers and herders have evolved as responses to reduce the impacts of these periods of acute hunger, which are too common events in many parts of Africa. These include diversification of crop and animal production, root crop production, collecting wild foods in the bush, as well as many social mechanisms. Other responses—such as seeking non-farm employment or migration—are not examined here.

One characteristic of low-resource production systems that reflects a concerted effort to buffer against famine is the raising of different crop and livestock species and varieties (56). This diversification minimizes the risk of total crop failure. In addition, it reduces the incidence of food shortages by ensuring some production during year-to-year fluctuations in climatic conditions, increasing expected returns by fitting various types of crops to particular micro-environments, and by spreading food production throughout the year. Herders achieve similar goals by raising several livestock species. Multi-species herds make better use of available pasture and offer a more continuous supply of food because of differences in periodicity of growth, milk production, and reproductive cycles (16,20).

Another buffer against famine is the common practice of growing roots and tubers. Because most roots and tubers in Africa are grown under low-resource conditions they are sometimes referred to as "poor peoples crops." Cassava, for example, is a highly productive staple that grows in low-fertility soils where few other crops can. It requires little labor to produce, and can be stored—simply left unharvested in the ground—until the hungry period between harvests. The fact that cassava is a staple crop among the poor has been partially responsible for its neglect among agricultural researchers (51).

Resource-poor farmers may also make extended use of undomesticated plants and animals during hungry periods. Farmers and herders often have a wealth of information on various wild resources, and may directly or indirectly promote their growth in surrounding

Photo credit: Consortium for International Crop Protection

Cassava is a "poor people's crop" because it grows where little else can, requires little labor to produce, and can be stored in the ground until seasonal food shortages strike.

areas. Although collecting wild foods and products can be important to household nutrition and income throughout the year, the collection of wild foods increases during hungry periods and certain wild foods are used only during these times (8,18,44).

Resource-poor farmers also have established a variety of social mechanisms to help seriously affected households survive periods of food shortfalls. These social mechanisms may be based on relationships such as kinship, affinity, or patron-client relations. For example, reciprocal food sharing is sometimes used to minimize starvation in a community while food supplies last (51). Livestock may be loaned to a household that has suffered serious losses of their herd. The loan arrangement economically benefits the lender by increasing the labor available to tend the herds, while the borrower receives milk, manure, and perhaps, rights to the progeny (62).

Most low-resource farmers and herders are relatively isolated from national markets and this is a major reason why these individual efforts to provide buffers against famine are so important for African food security. This was vividly illustrated during the mid-1980s drought: serious food shortages occurred in countries that actually had excess food, but governments were unable to transport and market it in the drought-affected areas. Also, small-scale farmers without other sources of income and pastoralists who depend on selling animals for cash must use their crops and animals themselves during a famine. As a result, they, along with landless agricultural workers, often lack the purchasing power to buy food even if it is available during a famine (79).

Therefore, an important aspect of dealing with food security issues in Africa is not simply the availability of food within the country, but also whether the vulnerable populations have access to it. For much of Africa this means promoting improvements among low-resource agriculturalists and, at the same time, not disrupting those mechanisms used to buffer against famine.

LOSING GROUND: CONCERNS FOR AFRICAN AGRICULTURE

African agriculture has continuously, and for the most part effectively, adapted to meet changing conditions. But never before has it had to respond to the level of pressures it currently faces. Paramount is the pressure created by rapidly growing populations and the consequent demands on the land. The resulting negative changes in agricultural land use are evident in most regions—reduced fallow, falling yields, and natural resource degradation. Per capita food production and income, as well as nutritional levels, are dropping. Although the severity of the problems varies greatly among countries, the overall threat is serious and likely to get worse before it gets better.

Africa's Population Challenge for Agriculture

The African continent has the most rapidly growing population in the world. The estimated rate of population growth is 3 percent per year, a rate that increases Africa's population by 1 million people every 3 weeks. Although the

United Nations and the World Bank project that population growth will drop to 1 percent by the year 2045, at current rates of growth Africa will have three times its current population to feed in just 40 years (83).

Population density in Africa, however, is relatively low, with an average of about 60 people per 100 hectares of cultivable land. This is about one-third the average for the developing world (79). These averages, however, hide the severe consequences of high population growth in those areas where population concentrations are already great, and in areas lacking the resources to support dense populations. For example, resource scarcity and intense population concentration are already acute in countries such as Rwanda and Burundi where the population densities are the greatest in Africa. Farm size in some parts of Kenya, where population is growing at an estimated 4 percent per year, now averages no more than 1 hectare.

In the past, the widely used practice of shifting cultivation was an effective traditional agricultural system in most parts of Africa. This is a form of production where farmers use simple tools to clear the land, then burn the debris so the ash serves as fertilizer. They leave or prune useful shrubs and trees. Then they plant seeds or other material, cultivate the site for a few years, and move to another area when yields fall and weeds begin to suppress crops. The previously cultivated site regenerates naturally during a fallow period until the cycle begins again (54).

Although scientists formerly viewed shifting cultivation as a primitive and inefficient form of farming, they increasingly recognize it as a culturally integrated, economically rational, and ecologically viable practice. This holds true, however, only as long as population densities are low enough to ensure adequate fallow periods to regenerate soil fertility and a new vegetative cover (61).

In many parts of Africa today fallow periods are too short. For example, fallow periods have been reduced from 12 to 2 years in Burkina Faso and from 20 to 5 years in Angola (4). When the average fallow period dropped from 5.3 to 1.4 years in Nigeria, cassava yields fell significantly (35).

This raises a fundamental problem for African farmers: can local innovations and adaptations in their current farming practices ensure their food security while facing the pressures of increasing population densities? Quantitative study of this issue is largely lacking. However, one study in Nigeria raises serious concerns by concluding that:

> (Farmer) adaptations were obviously able to slow the process of diminishing yields (resulting from reduced fallows), but they are insufficient to stop the process . . . Without additional income from off-farm employment, the households in high population density areas could not provide their daily food requirements (35, p. 116).

Although this conclusion relates specifically to a Nigerian case study, the general conclusions regarding the declining sustainability of many low-resource food production systems can confidently be extended to numerous other regions. One study, for example, concludes that 22 countries in Africa (including North Africa) were unable to feed their populations from their own land resources with existing practices as early as 1975. The number of countries unable to meet their needs with their own land resources is projected to reach 29 by the year 2000 (representing 60 percent of the region's total population) in the absence of significant increases in inputs and conservation measures (68).

Signs of Decline in African Agriculture

A number of additional signs indicate serious problems ahead for Africa's low-resource farmers and herders. For instance, declining per capita food production and income are making it more difficult for Africans to grow or acquire enough food to meet adequate nutritional standards. Perhaps the most insidious aspect of the problem is the inter-locking and self-reinforcing nature of these negative trends—namely poverty, malnutrition, poor agricultural performance, and environmental degradation.

Declining Per Capita Food Production

Africa's food problems are not caused by decreasing food production—the production of many food crops has actually increased—but rather by increasing population growth (72). Although total food production increased 1.8 percent annually for Africa as a whole between 1980 and 1984, population growth outpaced these increases. Therefore, per capita food production fell 1.3 percent annually between 1971 and 1984. Some exceptions exist, however, where specific countries have had significantly lower per capita declines and, in a few cases, increases (72).

Lags between food production and demand have caused a need for increased food imports. The changing balance between exports and imports of basic foodstuffs in Africa (including wheat, rice, coarse grains, and dairy products) reflects the negative effects of Africa's declining food production and increasing demand. From the late 1960s to the late 1970s, Africa changed from a net exporter of staple foods to a net importer, with food imports rising by 140 percent and exports declining by 52 percent (59). The value of exports in 22 countries in 1986 was not sufficient to pay for imports (72). In this way, low-resource agriculture's failure to keep pace with population growth also has contributed to the problems of trade deficits and scarcity of foreign exchange.

Declining Per Capita Income

Although low-resource agriculture has been a primary source of income in Africa, the income provided has not been adequate to ensure food security. Per capita income in Africa's low- and middle-income countries decreased by an average of 0.4 percent per year during the 1970s. For comparison, low-income countries in Asia saw increases in per capita income of 1.1 percent per year, and middle income countries saw a 5.7 percent increase during the same period (36).

Not only is the overall trend in Africa toward decreasing incomes, it is also one of increasing maldistribution of incomes and income-producing resources, such as land and livestock. For example, in Nigeria the share of land owned by the poorest farmers has decreased while the share owned by the richest farmers has increased. In Botswana and Somalia, the higher economic groups among the pastoralists increasingly control most of the livestock (21).

Declines and fluctuations in income have particularly severe effects on Africans because a greater percentage of their income is spent on food than in other parts of the world. For instance, Tanzanians spent about 60 percent of their total income on food in 1975; in Niger, people spent almost 65 percent. This can be compared to Hondurans who spent about 45 percent; Japanese, approximately 20 percent; and Americans and Canadians, who spent 10-15 percent of their incomes on food (41). This trend particularly affects the urban and rural poor, who spend a greater proportion of their income on food than the wealthy (21).

Increasing Malnutrition

Under normal circumstances, low-resource agriculture provides most countries in Sub-Saharan Africa with adequate dietary energy supplies (DES, a measure in kilocalories/per capita/per day). Dietary energy supplies in 31 African countries are near or above the average recommended requirement of 2,100 kcal per day. Ten countries, however, have DES levels that do not reach the recommended level and four of these are near or below the critical requirement of 1,800 kcal/day (72). Even within countries with acceptable DES levels, some people eat less than an adequate level.

These dietary trends provide further evidence that low-resource agriculture's ability to meet Africa's food needs is declining. Sub-Saharan Africa is the only region in the world where the dietary energy supply has declined over the past decade (72). In 1980, an estimated 150 million people in 37 African countries did not receive enough calories to support an active working life and, of these, 90 million did not receive enough to prevent serious health risks (79). As many as 90 percent of the malnourished people in Sub-Saharan Africa are poor agriculturalists (39). Their malnutrition is chronic but periods of acute food shortage occur during the planting season, just when people most need their strength to continue farming (76).

Deteriorating Natural Resource Base

Resource degradation problems vary by region, but almost all of Africa is affected (table 3-3). Approximately 35 percent of non-"desertified" land in Africa currently is at risk of future desertification (73). At risk are such important resources as soil quality and vegetative cover, including trees.

Soil erosion, salinization, and drainage problems are causing physical and chemical degradation of African soils, and reducing land productivity. Water erosion is the major cause of soil loss in Africa. Wind erosion is also a problem, particularly in more arid regions. Compaction or crusting of the soil caused by shortened fallow periods, reduction of soil organic matter, and improper mechanical tillage are sources of serious degradation of the soil's physical properties. Crusting can reduce the amount of water entering the soil, increase water runoff and erosion, and make it difficult for farmers to till the soil and for seedlings to emerge (72). Agriculture is "mining" the soil in many areas—removing more nutrients than it is putting back into the system through fallows, organic and mineral fertilizers, and rotations with nitrogen-fixing species.

These factors can significantly impair soil productivity and agricultural yields. The nature and extent of the impact varies by soil type and cultivation practices. FAO has estimated that without adequate conservation measures, the area of rainfed cropland in Africa will decline by 16.5 percent by the year 2000 because of land degradation. The loss of this land, plus the loss of soil quality on the remaining cropland, would lead to a loss of about 25 percent of Africa's land productivity (68).

Africa's three main types of vegetative cover—tropical rainforest, savannah woodland (or open forest), and rangeland—are all being

Table 3-3.—Summary of the Most Serious Environmental Degradation Problems by Region

Region	Arable Land	Grazing Land	Forest Land
Sudano-Sahelian Africa	Decline in nutrient levels in the soils Decline in soil physical properties Wind and water erosion	General degradation of vegetation's quality and quantity Wind erosion in sub-humid areas	Degradation of vegetation
Humid and Sub-Humid West Africa	Decline in nutrient levels in the soil Decline in soil physical properties Water erosion	Degradation of vegetation Wind erosion in sub-humid areas	Degradation of vegetation
Humid Central Africa	Degraded soil physical properties Degraded soil chemical properties		
Sub-Humid and Mountain East Africa	Water erosion Degradation of soil physical properties Degradation of soil chemical properties	Degradation in quality and quantity of vegetation Water erosion	Degradation of vegetation Water erosion
Sub-humid and Semi-Arid Southern Africa	Water erosion Degradation of soil physical properties Degradation of soil chemical properties	Degradation in quality and quantity of vegetation Wind erosion Water erosion	Degradation of vegetation Erosion

SOURCE: U.N. Food and Agriculture Organization, *African Agriculture: The Next 25 Years, Annex II, The Land Resource Base* (Rome, Italy: FAO, 1986).

degraded or lost (4). Reliable data on deforestation is lacking for much of Africa, but an estimated 3.7 million hectares of forest are cleared every year (71). Tropical rainforests are being cleared primarily for agriculture and commercial logging, and the highest rates occur in the West African coastal countries. Savannah woodlands are being cleared for fuelwood, livestock grazing, farming, and construction materials. Rangelands are being cleared by overgrazing and the expansion of farming (4).

Significant resources are lost when land clearing is rapid and unmanaged. Trees, shrubs, and grasses help control erosion and maintain soil fertility. Trees are capable of recycling nutrients and reaching moisture at soil depths beyond the reach of most crop roots. In addition, trees and shrubs are essential to meet the fuelwood needs of low-resource agriculturalists. Wood is the primary fuel in Africa and deforestation is creating shortages. Data show that all of Sub-Saharan Africa, with the exception of the humid central region, will suffer a fuelwood deficit by 2010 (72). Fuelwood scarcity affects low-resource producers by increasing the time they must spend collecting it or the money they spend to purchase it. For example, the radius of fuelwood collection around Nouakchott, Mauritania expanded from 10 to 70 kilometers between 1970 and 1980 (4). Between 1970 to 1978, the price of fuelwood increased almost 10 percent per year in Ouagadougou, Burkina Faso (80). Wood deficits also can harm soil fertility because when wood is lacking farmers will use crop residues and animal manure for fuel instead of fertilizer (80).

OBSTACLES TO IMPROVING PRODUCTIVITY AND FOOD SECURITY

Low-resource agriculture currently is not meeting Africa's food security and agricultural development needs and productivity in low-resource agriculture is loosing a race with population growth. Most experts agree, however, that low-resource agriculture can be improved. This will require greater efforts by African governments, development assistance agencies, and the agriculturalists themselves in dealing with obstacles to enhancing low-resource agriculture. These obstacles are internal to the farming system, such as biophysical and socioeconomic constraints, as well as external to the farming systems. These latter factors include unsupportive policies, infrastructural weaknesses, and underdeveloped technical institutions.

Biophysical and Socioeconomic Constraints

One problem that confronts planners in Sub-Saharan Africa is that the average level of agricultural productivity is generally much lower than in other regions of the world. For example, cereal yields in Sub-Saharan Africa are about 50 percent less than yields in Latin America, and yields of roots, tubers, and pulses are 30 percent lower than yields in Asia and Latin America (9). This poor performance can be attributed primarily to biophysical and socioeconomic constraints within the farming systems.

Generally, African soils are low in fertility; rainfall is unpredictable in many areas and low across much of the continent. At least 44 percent of Africa is subject to drought conditions, 18 percent of the area has soil affected by mineral stress (toxicities and deficiencies), 13 percent of the soil is shallow, and 9 percent is affected by water stress. This accounting, while hampered by uncertain and sparse data, suggests that only 16 percent of Africa's total land area is without serious biophysical limitations for agriculture (65).

Over the past two decades, at least two-thirds of Africa's food production increases have been gained by expanding the area cultivated (55, 59). Only one-third of the gains have come by increasing the output per hectare through intensification. Yield increases range from about 50 percent in eastern and southern Africa to virtually none in West Africa (59). The role of expansion onto uncultivated lands is decreasing since cultivation is extending into increasingly marginal lands with lower production potential (42).

For Africa to meet its future food needs and avert serious environmental problems, a far greater proportion of its food production gains must come from intensification and yield improvements, and a smaller proportion from expanding the cropping area. Estimates by FAO, for example, suggest that by the year 2000 about one-half quarter of the necessary food production gains should come from yield increases, about one-quarter from increased cropping intensity, and about one-quarter from expanding the amount of arable land (66). This would require a dramatic shift in approach and presents numerous difficult challenges, although considerable regional variation exists in how rapid and how urgent such shifts need be (68). For example, agriculture in Rwanda has little room to expand in area, whereas in other countries, particularly in central Africa, population density and consequent pressure on land is still low (4,45).

Intensifying agricultural production in Africa presents many difficulties, particularly for Africa's resource-poor farmers and herders. First, agroecological factors can restrict the extent to which intensification is possible (5). For example, in low rainfall zones, opportunities to develop more intensive farming systems can be severely restricted by slow vegetative growth. Developing permanent cultivation systems in these regions, where possible, can seri-

Photo credit: Jerry Frank/U.N. Food and Agriculture Organization

This rice field is an experiment in agricultural intensification. The Liberian government, with assistance from the United Nations, is carrying out research and training personnel at the College of Agriculture and Forestry.

ously undermine the viability of pastoralist production systems in surrounding areas by denying herders access to essential dry season fodder. At the other climatic extreme—high rainfall areas—problems of soil leaching and acidification, as well as high incidence of pests and pathogens, can seriously limit more intensive cultivation and livestock rearing. Medium rainfall areas (i.e., 750 to 1,200 mm per year) and some areas of the humid highlands offer the highest potential for permanent intensified cultivation (5).

More intensive agriculture also generally involves a greater investment of labor and capital. This raises problems for resource-poor farmers who rely on household labor and have little money to invest in intensive practices. For example, more intensive production such as increasing the growing period relative to the fallow period can greatly increase the need for weeding and place excessive demand on household labor. Maintaining adequate soil fertility under conditions of intensified production may also require supplemental fertilizer use, requiring either an additional labor investment (e.g., rearing animals for manure) or additional cash to purchase fertilizer.

Adopting conservation practices to maintain soil fertility, such as building terraces, can also require considerable investment from the resource-poor farmer. Land tenure problems also complicate matters in low-resource agricultural systems. Farmers are generally unwilling to invest in the long-term benefits of conservation practices unless they know they will reap the future benefits. Finding sustainable technical and institutional answers that encourage the intensification of farming systems and yet are economically feasible and socially acceptable to resouce-poor farmers is a central challenge for development assistance in Africa.

Unsupportive Policies

National and donor policies often have not been designed to benefit low-resource agriculturalists; in some cases, policies have harmed resource-poor producers. Three types of these policies are discussed here: national policies regarding expenditures on agricultural development, agricultural pricing policies, and policies concerning the development of technology.

Expenditures on agricultural development in Africa reflect the relatively low importance agriculture has as an economic development strategy in the eyes of policymakers (2,58,64). Many African governments spend no more than 10 percent of their national budgets on agriculture even though an average of at least 50 percent of Africa's gross domestic product, employment, and foreign exchange depends on the agricultural sector (69). For example, while 70 percent of Botswana's labor force works primarily in agriculture, the government spends only 1 to 3 percent of its gross fixed investment in the sector. About 80 percent of Kenya's labor force works in agriculture, yet the government invests about 8 percent. Zimbabwe has the highest investment—12 percent in a country where 57 percent of its labor force works in agriculture (39).

National pricing policies have been criticized for their disincentive effects on agricultural production and rural income. Government marketing agencies that buy commodities from farmers regularly establish prices below their true market values. In this way they collect so-called "hidden taxes" from farmers, especially for export crops. This practice also enables governments to provide cheap food to urban populations (34, 78). Such policies can provide serious disincentives for production and make it unprofitable for producers to buy agricultural inputs. The institutions used to carry out such policies have also been criticized as ineffective, primarily the parastatal organizations that often control agricultural supplies and crop marketing.

The relative importance of pricing policy as a constraint on the enhancement of low-resource agriculture is not yet clear. Experts who believe pricing reforms are important argue that positive changes already have led to some significant increases in production and income (26). Other experts, however, are less convinced of the importance of pricing policies relative to other development needs. These critics also contend that the benefits of pricing reforms have often gone to the minority of better-off farmers while bypassing, or in some cases hurting, the resource-poor agriculturalist (21).

Research and technical development policies have been criticized for being misguided and resulting in technological interventions that have failed to significantly improve low-resource agricultural systems. In some cases, interventions have actually upset the equilibrium of the old methods of land use without producing equally balanced new systems of farming (14). These problems arise because introduced technologies are often inappropriate for resource-poor farmers and herders (12)—whether for economic, social, managerial, or environmental reasons. Too often research efforts have focused on export crops or sophisticated systems that are out of reach for most farmers and herders and they have failed to account for the restricted access to and affordability of agricultural inputs (e.g., hybrid varieties, irrigation, and fertilizer).

Another problem has been that introduced technologies often ignore the reality of how African agriculture is actually practiced. For instance, farmers seeking to improve their intercropping systems necessarily suspect techniques designed for monocropping systems (19). The role of women in agricultural production, postharvest food processing, and household chores often has been neglected and technical interventions have been inappropriate, and thus unused, because they do not meet women's needs and priorities (33).

Infrastructural Weaknesses

Low-resource agriculture suffers from infrastructural weaknesses that make it difficult to take advantage of improved technologies. These include inadequate rural institutions for saving and lending money, lack of rural transportation networks, and poorly developed distribution systems for providing agricultural inputs.

The official rural financial systems of Africa function poorly, at best (37) and are nonexistent in many isolated areas. Existing institutions often do not provide credit for producers to grow staple foods. They also deny credit to most women because usually women lack collateral. Official interest rates are often subsidized, making credit a bargain that is often monopolized by economic and political elites (49). Local investment opportunities are lost, then, because appropriate ways to promote rural-based savings and lending among resource-poor farmers, herders, and fishers are missing (38).

The costs of providing formal credit to resource-poor farmers are often a disincentive for formal financial institutions (70). While formal credit opportunities are few for resource-poor producers, informal sources do exist. Informal savings and loan associations, which are locally managed, socially regulated, and knowledgable about the creditworthiness and financial needs of the rural poor, often serve rural populations not addressed by the formal sector. Given adequate incentives, many of these could grow to reach a larger population while providing credit at lower cost than formal banks (37, 49).

The lack of adequate transportation such as roads and rail systems throughout Africa is a major constraint to the delivery of inputs to farms and the transportation of food or other commodities to markets. The primary means of transporting agricultural products today is "headloading"—carrying them on one's head. In 1982, only 206,177 kilometers of roads existed in Africa's 14 landlocked countries. Among these countries, Zimbabwe had almost one-third of all roads and about 8,000 of the total 19,850 kilometers of paved roads (11).

Most of Africa's railroads were designed during the colonial period to link areas producing agricultural exports and minerals with the ports that would distribute them for the colonial powers. Lusaka, Zambia, is therefore linked by rail with Dar-es-Salaam, Tanzania; Uganda, Burundi, and Rwanda are linked with Mombasa, Kenya; and Bamako, Mali is linked with Dakar, Senegal, etc. Central Africa, because of vast distances from a port, has no major rail links in spite of its agricultural potential. Because of low population densities in central Africa and other regions, the costs per capita to provide roads and other services are much greater than in other regions of the world (36).

The inadequacy of the systems for distributing and marketing external inputs is another constraint on low-resource agriculture. When external commercial inputs do arrive in rural Africa, they are often labeled and packaged improperly (36). Seed and fertilizer deliveries may not be synchronized and delays in the arrival of pesticides may make them less than effective (57). Africa ranks last in developing regions in the percentage of irrigated land, tractors per 10,000 hectares, and fertilizer use per hectare (table 3-4). If commercial inputs are to be used by more agriculturalists in Africa, better delivery organizations and a better transport infrastructure are essential.

Underdeveloped Technical Institutions

Low-resource agriculture in general, will need to become more intensive to meet the food security needs while balancing the need to maintain the natural resource base. This change will, in part, depend on technical developments and the spread of their use among agriculturalists. Total funding for agricultural research has been declining in Sub-Saharan Africa. Expenditures by national governments for agricultural research decreased $80 million between 1980 and 1984, from $465 million to $385 million (46).

Table 3-4.—Modern Input Use in Africa, Asia, and South America, 1977

Area	Percentage of irrigated land	Tractors per 10,000 hectares	Fertilizer used per hectare
	Percent	Number	Kilograms
Africa	1.8	7	4.4
Asia	28.0	45	45.4
South America	6.1	57	38.8

SOURCES: U.N. Food and Agriculture Organization, *Production Yearbook*, and *Fertilizer Yearbook* (Rome: 1978). Cheryl Christensen, et al., *Food Problems and Prospects in Sub-Saharan Africa: The Decade of the 1980's*, Foreign Agricultural Research Report No. 166 (Washington, DC: U.S. Department of Agriculture, Economic Research Service, August 1981).

Also, research priorities often do not reflect food security needs. For example, in 1983 British foreign aid funding for tobacco research in Malawi was about twice as much as it was for millet research (77). Cassava is a staple food in many parts of Africa but only Nigeria (with a $2.7 million investment) and Ghana (with a $0.9 million investment) spent at least $50,000 on cassava research in 1976. Although the International Institute of Tropical Agriculture (IITA) has made some advances in cassava research, national programs primarily are responsible for developing varieties adapted to and accepted by local farmers (39). These programs often do not have adequate budgets or rank high enough in national governments' priorities to have a major impact on food security needs.

Extension systems in African countries also face many problems. They generally lack staff, supplies, and technical support, and inadequate communication exists between researchers, extensionists, and farmers. They also suffer from a lack of appropriate and profitable technologies to transfer. Some critics argue, then, that extension's problems originate with the lack of research and that, under existing agricultural budgets, research deserves a higher priority (32).

Another problem with most extension services is that they focus on providing information and inputs for export crops rather than food crops. In addition, the approaches used are generally "top-down," with the information flow in one direction—from the researcher through the extension agent to the male farmer (69). Women, the major food producers in many regions, often are not provided with relevant services. Non-formal education for African women most often covers their non-income generating activities, including home economics and nutrition (6), but they have limited access to training activities dealing with income-related activities such as cooperatives, agricultural production, and animal husbandry. Considering the major role of women as food producers and caretakers of livestock, this is a serious failure of the system.

Ensuring good staff for extension, research, and other agricultural services is another problem (36). Low-quality facilities, low salaries, undesirable living conditions, and the lack of status associated with working for traditional farmers are not attractive to trained personnel (36). Research staff turnover rates are high: at the Nigerian Institute for Agriculture, for example, staff turnover was about 80 percent between the 1960s and 1970s (46). In addition, governments spent three to ten times more for skilled staff such as researchers in Africa than in Asia in part because of a reliance on higher-salaried foreign scientists. These high costs make it difficult for African countries to expand national research systems.

A substantial increase in funding for research and personnel occurred between 1970 and 1980 (table 3-5). However, since 1980 a general decline in research expenditures has occurred (29). At the same time the number of scientists involved has grown, compounding the impact of recent budget declines in terms of level of support per scientist.

In many African countries, a high proportion of budgets cover salaries versus operations. This can be a serious obstacle to producing needed high-quality research and technology development. For example, some institutions allocate only 5 percent of their budgets to operations and maintenance, compared to a desirable figure of at least 30 percent (29). This places serious limitations on the funds available to get researchers into the field. As long as researchers are isolated from agriculturalists, questions will arise regarding their ability to address the on-farm problems of low-resource agriculture effectively.

Removing these all-too familiar obstacles will not be easy. The process is likely to take at least a generation, even if significant increases in resources were available today. Heightening the challenge is the realization that African countries will have double the number of people to feed and employ within the next several decades. The industrial and urban sectors cannot effectively absorb or provide for large portions of these people. The continuing dependence on rural employment and local food production by large numbers of Africans is thus inevitable. However, signs of decline in African agriculture underscore the urgency of better addressing the problems and potential of Africa's largest group of farmers, herders, and fishers. The following chapters outline one approach to enhancing low-resource agriculture in Africa.

Table 3-5.—Level of Support for Agricultural Research in Different Regions

	Expenditures (in millions of constant 1980 U.S. dollars)			Scientist Years		
	1959	1970	1980	1959	1970	1980
Western Europe	275.0	918.6	1,489.6	6,251	12,547	19,540
North America	668.9	1,221.0	1,335.6	6,690	8,575	10,305
Oceania	91.6	264.0	386.8	1,759	3,113	3,302
Latin America	79.6	216.0	462.6	1,425	4,880	8,534
Africa	119.1	251.6	424.8	1,919	3,849	8,088
North Africa	20.8	49.7	62.0	590	1,122	2,340
West Africa	44.3	91.9	205.7	412	952	2,466
East Africa	12.7	49.2	75.2	221	684	1,632
Southern Africa	41.3	60.8	81.8	696	1,091	1,650
Asia	261.1	1,205.1	1,797.9	11,418	31,837	46,656

SOURCES: U.N. Food and Agriculture Organization, *African Agriculture: The Next 25 Years, Annex III: Raising Productivity* (Rome: Italy, FAO, 1986). M. Judd, J. Boyce, and R. Evenson, "Investing in Agricultural Supply: The Determinants of Agricultural Research and Extension Investment," *Economic and Cultural Change*, vol. 75, October 1986, pp. 77-113. (Courtesy of the University of Chicago Press).

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Chapter 4

A Resource-Enhancing Approach to African Agriculture

CONTENTS

Page
Highlights . . . 77
Why Focus on Low-Resource Agriculture? . . . 77
A Resource-Enhancing Approach to Development Assistance . . . 78
  Agricultural Systems for Africa's Future . . . 79
  Diversity and Flexibility in the Face of Adversity . . . 80
  Untapped Resources for Development . . . 84
  A Complex Web of Connections . . . 86
A Resource-Enhancing Approach: A Comparative Assessment . . . 88
African Perspectives . . . 92
Chapter 4 References . . . 94

Boxes

Box *Page*
4-1. Turning the Tide at Guesselbodi . . . 81
4-2. Diversity in the African Home Garden . . . 82
4-3. *Acacia albida*: An Indigenous Resource for Development . . . 85
4-4. Changing Farming Systems of the Nyiha of Tanzania . . . 87

Chapter 4

A Resource-Enhancing Approach to African Agriculture

HIGHLIGHTS

- Meeting future food security needs in Africa will require that increased attention be directed toward assisting African low-resource agriculture. This conclusion is based on low-resource agriculture's central position in African economies today, its economic and technical potential to contribute to national and local development tomorrow, and the serious implications of continued neglect of this sector.
- Understanding the diversity and complexity of low-resource agricultural systems provides essential guidance on how development assistance can contribute most effectively to sustainable agricultural development.
- A proposed resource-enhancing approach is complementary to, and in some respects overlaps with, other defined African agricultural development strategies that focus on: 1) basic human needs, 2) the need for policy reform, and 3) targeted development of high-potential, small farms. Differences also exist, however, that have other implications for development assistance.
- A resource-enhancing approach generally is consistent with the views of African scientists and policymakers expressed to OTA.

WHY FOCUS ON LOW-RESOURCE AGRICULTURE?

Assistance to Africa's resource-poor farmers, herders, and fishers could have a substantial impact on African food security and agricultural development. Thus, low-resource agriculture deserves increased attention from development agencies and African governments (1, 17,27,33,35,37). This conclusion is based on four factors:

1. Low-resource agriculture already plays a central, though largely neglected, role in African economies.
2. Economic advantages and widespread benefits can be achieved through focusing agricultural development efforts on Africa's small-farm sector.
3. Low-resource agriculture in Africa generally is efficient, given current availability and dependability of resources and information. Known and promising technological opportunities exist to improve efficiency, however.
4. Failing to provide increased support to this sector will likely mean a continued deterioration of Africa's food security, and accelerating degradation of its natural resource base.

Low-resource agriculture, as shown in chapter 3, produces the majority of Africa's food and employs the majority of its people. Historically, however, agricultural development efforts have focused on large-scale farms and ranches, in part to take advantage of potential economies of scale. However, under conditions that prevail in most African countries, the benefits of pursuing "small farm development strategies[1] involving labor-intensive, capital-saving technologies" are now generally recognized as a more economically viable approach (17).

Also, efforts to promote agricultural development in Africa must look beyond simply elevating aggregate agricultural production and seek the balanced economic growth and social development that will only be provided through increased attention to resource-poor agriculturalists:

> In brief, the economic advantages of achieving widespread increases in productivity among a country's small-farm units derive from the fact that they are the most feasible and cost-effective means of attaining the multiple objectives of development—the growth of output, expansion of opportunities for productive employment, narrowing income differentials, reducing malnutrition and excessively high rates of infant and child mortality, and slowing the rate of population growth (17).

The economic advantages of focusing on a broad-based effort to promote small-farm development derive, in large part, from the heavy dependence on family labor in most African farming systems. Small farms that depend primarily on household labor are more economically efficient than larger scale state or private operations (16,33).

Also, practices of low-resource farmers and herders are increasingly being recognized as efficient ways to balance scarce resources and meet multiple objectives. However, the existence of compatible technologies and the prospects of providing improved access to inputs and information suggest significant improvements are possible. For example, crop yields probably could be doubled within a decade if improved management practices and varieties that already exist were employed widely (see ch. 5).

Because low-resource agriculturalists are in many cases the principal agents causing the deterioration of the African natural resource base, this group truly needs options to encourage sustainable production. The problem is most acute in regions where farmers and herders are, for lack of alternatives, overworking the land or are forced onto increasingly marginal lands, in many cases leading to serious environmental degradation.

Perhaps the strongest arguments for focusing development assistance efforts on the resource-poor agriculturalists are rooted in humanitarian concerns. Simply stated, failing to direct attention to this group will, in large measure, shut a majority of Africans out of the development process. The threat arises that this group, in terms of production and consumption, may become relegated to "insignificant" elements of national economies that mainly receive attention within the context of famine relief (13). To avoid such a scenario necessarily will require efforts by development assistance agencies, but especially African governments, to more effectively integrate the needs and contributions of resource-poor agriculturalists into national development efforts.

A RESOURCE-ENHANCING APPROACH TO DEVELOPMENT ASSISTANCE

The following discussion focuses on four concepts that are central to a resource-enhancing approach that might be undertaken with poor farmers, herders, and fishers in Africa. Each concept, in turn, suggests the applicability of particular guidelines for development assistance in support of low-resource agriculture and each is illustrated by a box.[2]

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[1] Economic analyses are often framed in terms of "small farms" and do not address explicitly the effects of such approaches on herders. Some economic arguments apear to apply to the broader group OTA terms "low-resource" (which includes herders) but a definitive conclusion awaits further analysis.

These guidelines for development assistance are derived from a review of development successes and failures. They reflect the need for development assistance to be long-term, dynamic, and well matched to existing conditions. Also, these guidelines stress that to enhance low-resource agriculture, understanding existing systems must precede interventions. Most importantly, the development and application of African skills are crucial for reaching the goal of eventually eliminating the need for most development assistance.

The guidelines outlined here reflect a generally well-accepted view of low-resource agriculture in Africa. In fact, many of the guidelines are already reflected to some degree in existing legislation and official development assistance policy (see ch. 6) and are largely consistent with the views expressed by African experts surveyed by OTA (1; app. D). The guidelines are general because they are intended to respond to the diversity of low-resource agricultural systems and no attempt has been made to list all the ways in which the four concepts could be turned into guidelines. Basically, these guidelines are simple ideas, perhaps obvious ones. However, too often they have been ignored and development assistance has suffered as a consequence. What the guidelines imply for development assistance is addressed in general terms here; chapters 5 and 6 provide additional detail.

Agricultural Systems for Africa's Future

Concept 1: Most African agricultural systems, although once sustainable, are no longer keeping pace with the increased demands being placed on them. Thus, development assistance should be designed to:

- **place a high priority on environmental, technological, economic, social, and institutional sustainability;**
- **acknowledge the importance of sound natural resource management as a basis for improved and stable agricultural production; and**
- **acknowledge that resource-poor agriculturalists are the primary custodians of their resources, and therefore ensure that they benefit from development assistance to manage natural resources better; and**
- **focus on enhancing the capability of Africans to assume primary responsibility for their development as the surest route to sustainability.**

Sustainability of agricultural production systems should be a paramount objective for African agricultural development. Sustainable agriculture is a concept that has received considerable attention in recent years, but one whose criteria remain inadequately defined. Agreement on some fundamentals of the concept is growing, however. Sustainability of agriculture should be approached from various perspectives—environmental, technological, economic, social, and institutional. It is generally recognized that for agricultural development to be sustainable it must consider all these dimensions as well as their interaction (22,23).

Sustainability is fundamentally a temporal consideration—a condition of viability over time. It means, for example, not only that a technology is affordable today, but that costs and upkeep remain affordable tomorrow, or until replacement or upgrading becomes cost-effective. Institutional support services (e.g., for repair, distribution, or financing of inputs—as

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[2] The material in this chapter comes from several sources. OTA's Contractor Reports were used to develop an overview of the fundamental concepts underlying low-resource agriculture's management of natural resources, household productivity, and the effectiveness of institutions (10,11,18). OTA also held a workshop to integrate the findings from these papers (app. B) and supplemented this information with an additional contractor report and a workshop summary (app. A). Many other experts participated in the review of the information, but the final synthesis and conclusions are OTA's.

Box 4-1.—Turning the Tide at Guesselbodi

The Sahel is not an easy place to make a living, but people have been doing so for as long as 600,000 years. The region is characterized by sparse, erratic rainfall and what some scientists suggest is a cyclical pattern of drought every 30 years or so. Farming and especially herding activities are closely aligned to these fluctuations. With sufficient rainfall, farmers have extended their activities into drier areas and herders increased herd size and altered herd structures (e.g., increasing numbers of cattle relative to more drought-tolerant camels and goats). When drought set in, the pattern has historically meant a retreat to wetter areas and a shift to more drought-resistant crops and livestock. However, population growth in the region, among other factors, has made it increasingly difficult to revert back to the areas of higher and more dependable rainfall. The consequences are increasingly severe. After almost three decades of below-normal precipitation, a once gradual process of declining productivity and loss of biological diversity has now accelerated in many regions to the point of disrupting ecological processes essential to sustainable development in the region (29).

The impacts can be readily seen around the Guesselbodi Forest in eastern Niger. Guesselbodi was designated a national forest reserve in 1948. But authorities have been unable to prevent local populations from overexploiting the forest and land, through deforestation, overgrazing, and unsustainable farming practices. An estimated 40 to 60 percent of the forest cover was lost between 1950 and 1979, leaving behind barren land largely denuded of topsoil (15). Strong pressures also emanate from Niamey, Niger's capital, about 25 kilometers away. Niamey's population grew from 7,000 in 1945 to 300,000 in just 25 years; and with its growth came demands for food and fuel from surrounding areas. The result has been an ever-widening ring of degraded land around the city, as once viable pasture and farmland are left crusted and barren. It has become increasingly apparent that in order to meet the needs of existing residents, let alone the projected increased population, a more sustainable approach to exploiting the region's natural resource base is needed. Further, greater effort also must be directed to reclaiming land already degraded.

Guesselbodi is one place where development focuses on turning back the tide of environmental degradation. It is the most advanced of a number of similar pilot projects in Niger's Forestry and Land Use Planning Project currently funded by AID. A research and management plan was developed in 1983, based on soil and topographic surveys and inventories of vegetation and forest resources. The aim is to promote systems whereby multiple uses of the forest resources could provide sustainable benefits to the surrounding communities—e.g., fuelwood, poles, forage, honey, medicine, food, and income:

> The idea was to test simple, small-scale, low-cost rehabilitation measures that could be carried out by villagers. The first plots were covered with water harvesting and water spreading structures: microbasins, earth banks, stone lines, rock dams to divert flash floods from gullies onto slopes. The earth banks and lines are already collecting soil, leaves, and seeds and local tree species are regenerating spontaneously. Perhaps the simplest and most spectacular regeneration technique on crusted areas is a mulch of twigs and small branches—of the kind that would be left over after extraction of saleable branches for firewood. The brushwood accumulates soil, sand, organic materials, and seeds, but also lowers soil temperature, protects against raindrop impact, and attracts termites, which aerate the soil. In the first year, 1983, when control plots of untreated crusted land produced no vegetation, the mulched plots yielded 440 kilograms. But in 1984—a drought year—(nearby) plowed plots had recrusted and produced only 30 kilograms of vegetation; the twig-mulched plots yielded five times as much.

The success of Guesselbodi and similar initiatives ultimately will depend on the willingness of the local people to support them. Initial economic evaluations seemed encouraging (15). Early field results, however, showed problems. Some modifications resulting from farmer participation, and support from national authorities (primarily the granting of tax exemptions for forest products) seem to have resolved the major problems and the project is now showing promising results. Some 5,000 hectares of formerly degraded land have been reforested and are providing income and other services to villages and individuals, primarily through wood products and grasses. Although wood was initially envisioned by planners as the principal benefit, access to fodder has emerged as an equally important product as identified by local participants. Thus, the lessons of Guesselbodi also illustrate the importance of long-term support, local participation, and flexibility in project development (25).

well as markets for outputs) should be available to support innovations at the outset, but should also be able to evolve to meet continued needs as development occurs. Further, the ability of the natural resource base to support a particular activity should be evaluated using a long-term view, using the basic tenet of keeping renewable resources renewable (7,18,20).

In effect, the concept of sustainability must also be viewed in dynamic terms, given the changing demands placed on farming systems in Africa. It must be recognized that change, in many cases rapid change, will be the norm. In these circumstances sustainable agriculture means continued modification of agricultural practices, and in most cases intensification, in order to accommodate growing demands (7). In the face of these growing demands, increased attention must also move beyond simply ensuring sustainability of existing systems, and begin to restore productivity of already degraded systems (box 4-1).

Diversity and Flexibility in the Face of Adversity

Concept 2: Africa's heterogeneous mixture of resource-poor farmers, herders, and fishers have responded to a high degree of environmental uncertainty and economic vulnerability with diverse and flexible strategies. Often these strategies minimize risk while seeking optimum stable yields, commonly at the expense of maximizing yield. Thus, development assistance should be designed to:

- **Accommodate the diverse and flexible approaches typical of resource-poor agriculturalists. This would include enhancing their ability to manage risk, retaining their flexible household organizations, encouraging diversification of income-generating activities, and supporting indigenous experimentation and innovation in agricultural systems.**
- **Design; implement; monitor; and evaluate policies, economic strategies, and technologies for their differing effects on people of different ages, gender, ethnicity, and economic status since all practice low-resource agriculture.**
- **Have available a variety of interventions (policies, programs, projects, and institutions) so that the ones most appropriate to the varied and changing needs of resource-poor agriculturalists can be met. Long-term monitoring and feedback should be used to adjust development activities so they remain useful and relevant as people's needs and conditions change.**

Poverty and a heavy dependence on local resources, including household labor, give rise to certain common strategies among African farmers and herders. Among these strategies are planting numerous crop species, as well as multiple varieties of a particular crop. In the Congo basin, for example, it is not unusual to find as many as 30 or more different crops on a single farm (6; box 4-2). Equivalent strategies within pastoralist systems include mobility, maintaining large and diverse herds, and establishing social arrangements to gain access to increased resources during bad times (9). Chapter 3 outlines rationales for these various responses, but basically they represent strategies to:

- promote diversity of diet and income;
- stabilize production;
- minimize risk;
- reduce insect and disease incidence;
- use labor efficiently;
- intensify production within the constraints of scarce resources; and
- maximize returns under low levels of technology (2,14).

Heavy reliance on family labor sometimes creates surplus labor during parts of the year and labor shortages during other parts. African farmers accordingly have developed various practices that help moderate fluctuations in labor demands by, for example, cropping practices and sequences that spread labor demand, or reserving most nonagricultural activities for slack seasons.

The high degree of household and community self-reliance inherent in low-resource agri-

Box 4-2.—Diversity in the African Home Garden

The home garden (also known as a compound farm) represents one important means by which farmers have diversified the form of agricultural production and the types of commodities produced. Occurring wherever cultivation is possible, home gardens are cultivated across the agro-ecological zones of Africa though they differ considerably in size, shape, intensity of cultivation, and in type and number of species grown (30). Unlike the U.S. conception of a garden as a source primarily of vegetables, African gardens also include staples (e.g., maize, yams, cassava, and legumes), tree crops, oil crops, spices, and condiments. They may also provide a variety of non-food products, including animal browse, fuel, fiber, medicine, and ornamentals (30). They are important for direct household consumption and provision of cash income.

Home gardens are managed differently from other fields. They are commonly located on land closest to the homes of the farm families. Unlike the outlying fields which are extensively cultivated, home gardens are intensively farmed often on a permanent basis or with extremely short fallows. This intensive permanent cultivation is made possible by the application of animal manure, crop residues, and household refuse which help maintain soil fertility.

Home gardens also differ from other fields in the number of different crops grown, often in a multistoried structure. The number of stories and species decreases as one moves from humid to less humid areas. For example, gardens in the humid zone of Nigeria may have four stories of growth and up to 84 species of plants. The lowest story has such crops as sweet potato and melon growing along the ground. The next layer includes vegetables such as tomatoes and eggplant along with grain legumes and the seedlings of trees and shrubs. Cereals, such as maize, and small trees and shrubs make up the third layer and include citrus fruits, yams on stakes, and cassava. The topmost layer includes tall trees such as African breadfruit, oil palm, and wild figs. Besides these better known crops, a host of plants less well-known and less researched is grown.

Several benefits derive from the diversity of the home garden. Nutritionally, products of the garden provide essential nutrients that complement the crops and vegetables grown in outlying fields. In some cases, no other source for these nutrients exists. In addition, the garden supports production throughout as much of the year as possible thereby minimizing seasonal periods of food shortage. Agronomically, the multistoried and intercropped structure of the garden creates favorable microclimates for production, and plants are arranged accordingly. Solar energy is used at the various levels, weeds are crowded out, the impacts of pests and diseases are reduced, and the roots of the different crops reach different depths and take better advantage of soil moisture and fertility. Labor productivity on established gardens is high and is well distributed over the year. The garden is also used as an experimental area where new species and varieties may be tried (5,19,30).

Home gardens have received little study concerning their agronomic functioning and actual importance to nutrition and household economy (including the roles of men's and women's labor). Improved understanding of both of these areas could support improvements in gardening. Identified areas of possible improvement include: breeding varieties which fit into garden structures, identification and extension of underutilized useful species, improved management techniques, integration of animals, improved food processing and utilization practices and access to the needed resources necessary (e.g., water and land) (5,19,30).

culture also makes flexibility, such as the ability to reallocate resources in response to changing and unanticipated circumstances, an important aspect of African farming systems. Flexibility also is a function of the unpredictability and risk commonly associated with African agriculture, particularly in areas of erratic rainfall or high pest incidence. As one researcher expresses it:

> Farmers allocate their inputs under an intersecting matrix of constraints—soil moisture status, pest outbreaks, an unexpected illness, lack of ready cash, etc.—which can rapidly change . . . In the short run attention is concentrated

on the varying mix of constraints and events, which can have quite different implications depending upon the stage of crop maturity (28).

Many ways exist for development assistance to accommodate the diversity and flexibility needed in low-resource agricultural systems. For example, increased attention could be directed toward research in multiple crop farming systems (see ch. 8). It is also important to understand social structures currently operating in support of low-resource farming systems. It can be important, for example, to understand social mechanisms (within the household or community) that determine access to and control over on- or off-farm resources. It may be valuable to investigate how women's farming associations or savings associations, for example, may be pooling resources or reducing risks of individual investments through joint purchasing.

Helping diversify local and regional economies can increase the availability of income-generating activities (e.g., labor for hire, small trade, carpentry, crafts) while bringing stable markets for the sale of produce and the purchase of external inputs such as tools or fertilizer. Promoting indigenous experimentation and innovation with diversified production systems should be encouraged because it brings about adaptations to existing conditions and can serve as a basis for improvements in agronomic practices, seeds, or other features (11).

Photo credit: F. Botts/U.N. Food and Agriculture Organization

Women in Burundi diversified their activities by raising chickens cooperatively. The Burundi Department of Rural Development received support from the U.N. Food and Agriculture Organization to train farmers.

Development assistance must be aware of the existing division of labor common in Africa (i.e., by age or sex). Responsibilities for various tasks are allocated among household members to help balance labor demands in ways that reduce labor bottlenecks. Introducing technologies can disrupt the balance and undermine anticipated improvements. For example, introducing tractors to facilitate or increase land clearing (often men's work) creates increased, even excessive, demands for weeding the field (primarily women's activity). It should also be recognized that some mechanisms used by resource-poor households (e.g., remittances from male migrant laborers, seasonal hiring of short-term labor by female-headed households) may enhance on- and off-farm opportunities.

Institutionalized inequality of households and communities in Africa can create problems for development assistance. Agricultural extension, for instance, commonly fails to reach the largest group of farmers—women—because it is run by men and directed to men's needs. Development assistance practitioners must be sensitive to the diverse and complex cultural systems of Sub-Saharan Africa for their work to be accepted. But they should strive to remove obstacles to the equitable introduction of new technologies in order to ensure its effectiveness (11).

Development assistance must support technological change while recognizing the uniqueness and diversity of African agriculture and agriculturalists (18). Each production unit will respond differently to the introduction of new methods and ideas and development interventions will be successful only if they address the varied situations present (24). In addition, development assistance should recognize that a variety of public and private sector institutions potentially are available to serve resource-poor farmers. None of these institutions should enjoy a monopoly; none should be overlooked; each should be used where it will be most effective. In particular, development assistance should recognize that local, often small, informal institutions—not just larger or more formal institutions—are important to development activities since they are directly in touch with and accountable to local publics. Local institutions constitute an indispensable resource that governments and donors should encourage. Development assistance agencies also should promote institutions and activities that emerge from specific local needs, not from "blueprints," and they should help them evolve to accommodate technological, social, economic, and other changes (10).

Untapped Resources for Development

Concept 3: Local resources—such as local people's skills, knowledge, practices, and institutions, plus indigenous plants and animals—reflect adaptations to the diverse local conditions found in Sub-Saharan Africa. Thus, development assistance sould be designed to:

- **Make local participation an integral part of the initiation, design, implementation, monitoring, and evaluation of development assistance projects.**
- **Ensure that African women, who in the past have not received the share of development assistance that their role in agriculture warrants, become full participants in the development process.**
- **Make increased use of local organizations, including assistance to improve existing organizations.**
- **Build on local resources, such as indigenous plants and animals and people's knowledge of how to use them. These resources have been largely untapped by development assistance agencies and they often can be improved.**

Experts in agricultural development assistance increasingly view many traditional agricultural systems and the products they produce as valuable resources for Africa's development. In part, this change toward increased appreciation of these resources is a function of the poor track record development assistance organizations have had so far in finding alternatives. It also reflects, however, a greater effort now being directed toward understanding practices and research that shows that these practices represent efficient responses to meeting multiple objectives with often meager resources.

In investigations of African pastoralists, for example, a conclusion has emerged that:

> More and more often the livestock developer has come to realize that the practices of pastoralists make sense: animal breeds well-suited to multiple goals, herd management techniques adapted to local conditions, husbandry as up-to-date as the flow of information and technology permits, land-use management carefully adjusted to long-term social and subsistence insurance (12).

Much the same argument is made for crop and mixed crop-livestock production systems. Of particular interest are the genetic resources that have emerged to fit the particular needs of African farming systems. The varieties that have evolved over the course of hundreds of years of human and natural selection are inherently well suited to local conditions and, despite what are commonly viewed as low yields, are of critical value to low-resource systems (box 4-3). Evidence of their value is reinforced by the poor record of improving on their performance under resource-poor conditions and people's continued use of traditional cultivars in conjunction with "improved" varieties.

Local knowledge may also provide resources for agricultural development beyond those manifest in existing production systems. Evidence exists, for example, to show that populations have information on a range of production systems that may provide important sources for innovation and agricultural intensification. One researcher notes, for example, that:

> African ecological research suggests a continuum from extensive to intensive cultivation, with shifting cultivators not unaware of the costs and benefits of permanent field cultivation. From time to time cultivators may adjust their position back and forth along this continuum . . . (32).

Box 4-3.—*Acacia albida*: An Indigenous Resource for Development

Traditional African agriculture has long used existing resources to provide sustainable benefits. For instance, the use of *Acacia albida*—a fast-growing, leguminous tree native to Africa—is one of many practices that have been used for centuries. Historically, the tree was considered so valuable that in the Zinder region of Niger, a 19th century Sultan decreed that people found cutting *Acacia* trees would be beheaded. In Senegal, highly productive agrosilvipastoral systems have continued to evolve using the multiple benefits provided by these trees.

The species has several characteristics that are valuable in agricultural systems. For instance, at the onset of the rainy season the species drops its leaves. These leaves provide a leaf litter mulch that enriches the topsoil. During this wet season, which is when sorghum and millet are produced, the defoliated canopy permits enough light to reach the ground for cereal growth and provides enough shading to reduce the effects of intense heat. During the dry season, the *Acacia's* long taproot draws nutrients from beyond the reach of other plants and stores these in its fruits and leaves. These drop to the ground at the beginning of the next rainy season and are consumed by livestock. Because the fodder has more nutritive value per unit weight than many other fodder crops, more livestock can be supported than without the *Acacia*. In addition, the livestock manure helps enrich the soil further. Thus, crop yields are greater when an *Acacia* is in a field than when it is not (26).

Using the tree with a proper balance of crop and livestock can also considerably extend the length of cropping without loss of productivity. For example, using the *Acacia* helped maintain continuous cropping of millet in the Sudan for 15 to 20 years in areas where the norm was 3 to 5 years.

Today, the *Acacia* is being promoted by some development groups in an attempt to provide sustainable benefits to low-resource agriculturalists. Nevertheless, many Africans were well aware of the importance of the tree as a productive resource long before the Western researchers who now tout its qualities. It provides just one of many examples of indigenous resources and production systems once overlooked or denigrated, but now commonly recognized as valuable.

The implications of this are that farmers and herders tend to have a reservoir of latent knowledge of agricultural systems and local resources. This suggests that local farmers already may have done considerable "research" of their own on different forms of production. This information could provide valuable information on development options, but requires a concerted effort to tap it.

Despite the considerable wealth of knowledge and resources in low-resource agricultural systems, this alone will not be adequate for meeting Africa's future needs. Outside resources will be essential, in particular the application of modern science to African agricultural problems. Along these lines, however, a far greater investment needs to be made in bolstering the scientific capacity within Africa itself. In this way, African scientists—better placed to understand agriculture in their own countries—may be able to draw on knowledge and technology selectively from abroad and apply it to their own settings.

Enlisting the participation of resource-poor farmers and herders is essential in defining effective approaches to assist them. Local participation can come in many forms, including one-on-one approaches, communication with community leaders, community meetings, interaction with local and multi-village organizations or their representatives, and interactions with regional-level organizations or their representatives. Efforts to engage local participation are not without additional costs to donors and participants themselves. Therefore, effective participation depends upon identifying key places where local decision-making will most improve assistance (36).

A Complex Web of Connections

Concept 4: Low-resource agriculture in Africa is based on farming systems that have interacting ecological, social, and economic components, and these farming systems are linked, in turn, to other larger systems beyond the farm. Thus, development assistance should be designed to:

- **Account for the integrated nature of low-resource agriculture and how these interrelationships affect the success or failure of interventions.**
- **Improve the links between farms and external systems such as markets, extension systems, and transportation networks.**

The farming systems of Africa are complex and changing. Many interacting internal and external factors affect who uses the land, how it is used, with what techniques, and for what objectives.

One way to view the integrated nature of farming systems is to use a hierarchical perspective, where ecological, economic, social, and institutional factors operate and interact at different levels (22). At one level, for example, are various factors operating within fields, for example, agronomic considerations of soil quality and water availability, or social factors such as division of labor in field activities. On a broader level are activities taking place within the entire farming enterprise, including non-farming activities. Therefore, understanding how resources are used within farming systems requires looking beyond the household, given the importance of links among households:

> Investigations of numerous systems of rural production in Africa have demonstrated that viable production by individual farm households depends on their being embedded in supra-household networks. These supra-household linkages may take the form of mutual aid or have the character of patron-client relations. Whatever the form, it is clear that access to key resources or to basic factors of production lies outside the household as often as it lies within it . . . (31).

It is also important to consider agricultural development using a broader ecological framework that incorporates, for example, the environmental services (reducing run-off, controlling wind erosion, etc.) provided by natural areas beyond the farm. Disturbing these systems, as reflected in such processes as desertification and deforestation, increasingly undermines the viability of development in Africa. But protecting these resources depends on the area (e.g., the consequence of decisions made by many individual farmers given land tenure patterns) and beyond (e.g., the commitment of national government to resource planning and management).

At the national or regional level a variety of macroeconomic and national policy issues, although seemingly removed from the day-to-day operations of resource-poor farmers, can have major impacts. How a government structures its agricultural policies (e.g., pricing, credit, and extension) and such factors as monetary or fiscal policies can significantly influence the low-resource farmer. Even international factors, such as international commodity prices and international commodity agreements, can influence agricultural activities. For example, establishing access to international markets for particular cash crops can result in fundamental restructuring in local farming systems (box 4-4)

Enhancing the links between on-farm and external systems (e.g., markets, rural financial institutions, transportation networks, research and extenion systems, and off-farm income) will require the use of different institutions and combinations of institutions. Development assistance agencies should support a wide range of institutions—public and private, governmental and nongovernmental, local and regional—depending on their comparative advantages for specific activities. Their choice should serve rural publics and help people reduce their vulnerability to external influences such as unstable markets and inadequate extension systems.

> The ways in which interventions will change the relative weight of available production factors, and modes of access to those factors, require careful tracing, including both prior tracing of likely effects, based on available knowledge of linkages, and post hoc tracing, as part of the monitoring, evaluative, and directed feed-back processes of research (31).

Development assistance agencies can encourage these many layers of institutions to share

Box 4-4.—Changing Farming Systems of the Nyiha of Tanzania

Farming systems of the Nyiha people of Tanzania serve as an example of the complexity of low-resource agricultural systems and their changing links to external and internal factors. The rainy season usually lasts for 5 to 6 months in the Mbozi area, with annual precipitation averaging 40 to 50 inches (1,000 to 1,250 mm). This environment is suitable to produce the Nyiha's major staples—maize, millet, sorghum, legumes, and cassava—using a variety of traditional shifting cultivation techniques. These typically include several crop sequences followed by a fallow period.

Internal and external factors—e.g., increasing population pressure, the introduction of European-style coffee estates, and increased coffee production by resource-poor farmers—have caused major changes in local farming systems and their links with the export crop economy. As the area's population grew and as coffee production expanded, less land was available for food production. Some farmers migrated to less densely populated regions within the Mbozi area. Others intensified their food production systems, and still others incorporated coffee into their own annual labor cycle and household economy. The people who migrated continued traditional shifting cultivation. Those who intensified their food production began to replace shifting cultivation with various grassland-fallow management techniques, such as ridging, mounding, intercropping, legume/grain rotations, and production of cassava on marginal lands. Those who incorporated coffee into their household production systems mobilized male labor which was not typically involved in food production.

Each of these three groups requires a different form of development assistance. Shifting cultivators will need assistance in the transition to permanent agriculture as this becomes necessary in response to growing populations. Those that have already begun this transition can be assisted with technologies that promote sustainable production systems using their particular mix of resource endowments. Farmers growing some coffee might be assisted through efforts to adapt scaled-down techniques from larger coffee plantations. They use more inputs such as fertilizers and modern management techniques, and are able to rely on external institutional arrangements and marketing systems to obtain their inputs. On these farms, traditional food production meets most subsistence needs and provides some income, while coffee production provides additional income from exports (18).

information and coordinate their efforts. Development assistance agencies also can work with national governments to reform bureaucratic structures and procedures as necessary so they serve low-resource farmers more effectively (10). In addition, special attention should be given to encourage maintenance of diverse social connections between households, groups, other cooperative groups, and communities because these networks help reduce risk and serve the varied needs of low-resource agriculturalists.

A RESOURCE-ENHANCING APPROACH: A COMPARATIVE ASSESSMENT

A variety of approaches to development assistance exist and donors often use mutually supportive elements from several. A resource-enhancing approach would have elements in common with other strategies addressing agricultural development and some significant differences. To illustrate these similarities and differences, three donor approaches are compared and contrasted with a resource-enhancing approach. The three approaches are:

- The New Directions/basic human needs approach which sought to provide such basic human needs as food, education, and health care for the poor.
- The Accelerated Development/policy reform approach which has come to focus on reforming national policies that constrain economic development, including development of the agricultural sector.
- An approach promoting accelerated growth in food production, primarily in the highest potential regions, detailed by the International Food Policy Research Institute (IFPRI),[3] through increases in use of commercial inputs, infrastructure, and African institutional capabilities.

A resource-enhancing approach shares a common overall emphasis with these three strategies. All seek to develop agriculture as the primary means to support national development. Within agriculture, all four focus on the "small farmer" and not larger, commercial, or state run farms. The four strategies differ significantly, however, on how best to support the development of this group, and on what portion of this broad group should be addressed.

The United States' development strategy was redirected toward improving the lives of the poor by the 1973 New Directions legislation amending the Foreign Assistance Act of 1961. This change stemmed from criticisms that previous U.S. aid to developing countries was supporting inequitable economic growth and that it was not helping the poor who made up a significant and growing percentage of recipients (21). With this approach, the purpose of development assistance shifted to increasing the poor's access to food, health care, and education. The poor were to benefit through the direct provision of these basic human needs and by increased access to factors such as credit, extension, and improved infrastructure that could increase their productivity and income. Increases in income would then enable the poor to supply their own needs. Assistance was also intended to increase the poor's participation in and control over development. Because the majority of Africa's poor are agriculturalists, agriculture became a central focus of the strategy although attention was also given to the urban poor. Project aid was an important means of providing for basic human needs (16).

The impact of the New Directions strategy was limited both by conditions in Africa and by its actual implementation. These problems included:

- a lack of trained Africans to program development assistance funds and to run the projects;

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[3] Researchers associated with the International Food Policy Research Institute (IFPRI), 1 of 13 centers of the Consultative Group on International Agricultural Research, have recently detailed this approach in J. Mellor, C. Delgado, and M. Blackie (eds.), *Accelerating Food Production in Sub-Saharan Africa* (Baltimore, MD: The Johns Hopkins University Press, 1987). For this section, this approach is called "the IFPRI approach."

- a lack of improved agricultural technology to be transferred to poor farmers, inhibiting the potential for increases in agricultural production and income and thereby leading to a greater emphasis on the direct provision of basic human needs;
- a lack of indigenous institutions and trained personnel capable of generating agricultural technology and supporting the development of agriculture;
- the existence of national policies which discouraged increased agricultural production;
- projects' failure to generate the revenues needed to be self-sustaining;
- overly complex attempts to deliver different services and goods, combined with the unfilled need to coordinate differing bureaucracies;
- projects' failure to address local environmental and social conditions; and
- projects' failure to ensure beneficiaries' participation (16,21).

These constraints became evident as projects were implemented to carry out the New Directions strategy. Their identification was a key reason for the design of the other three approaches, which have responded to these shortcomings in different ways, and for modifying the New Directions approach itself.

Lack of national economic growth in Africa and the identification of the important role of national policy in this problem led to the more macro-economic approach of Accelerated Development, first detailed in a 1981 World Bank report, *Accelerated Development in Sub-Saharan Africa: An Agenda for Action*, prepared at the request of the African Governors of the World Bank. According to the Accelerated Development approach, changes in national policies (known as policy reforms) are key to national economic growth and three types of policies are of primary importance: suitable trade and exchange-rates; increased efficiency of the public sector; and supportive agricultural policies. Agriculture is seen as the most important determinant of economic growth. Means to support agriculture would include: a focus on smallholders with greatest attention paid to the highest potential regions, increased prices for agricultural products, more competitive markets, increased rural availability of consumer goods, improved transport and marketing infrastructure, increased research, and increased attention to export crops where a comparative advantage exists (38). Over time, donors have come to focus primarily on the policy reform aspects of Accelerated Development, giving less attention to those nonpolicy factors also identified in the approach; hence, the increased use of the term Policy Reform as a donor approach. Donors have also focused more on changing actual policies than building African support and capability to do so. They have concentrated on supporting a set of reforms which address such current policies as:

- below-market prices paid to farmers for their commodities, set by the government as a way to increase government revenue (especially from export crops) and to provide cheap food to politically important urban populations;
- overvalued exchange rates combined with import restrictions used to conserve foreign exchange, make food imports cheaper, and make food exports less remunerative for the farmer, imported agricultural technology more expensive, and consumer goods more expensive;
- a failure by the government to invest adequately in agricultural development; and
- an overreliance on parastatals for marketing agricultural inputs and outputs, which has led to inefficient marketing, high marketing and transport costs, and locking out the indigenous private sector (21,34,38).

In addition to the benefits incurred by changing such policies, Policy Reform is attractive because of how it can be implemented. Donors can move large amounts of assistance quickly in return for promises of policy change and thus meet their own budget timetables and react to domestic political needs. Measurable goals can be set, such as changes in exchange rates or prices, and can be reached relatively quickly thus meeting demands for documentable, fast results. In addition, expatriate personnel requirements are seen as lower than those necessary for New Directions' type project assistance and macro-level data analysis can occur at central locations. These justifications have been challenged, however, because some see reform as a slow process and note that personnel requirements are not reduced only shifted (3,4).

Policy Reform's approach and its implementation have raised several concerns over its impact. Its emphasis on national-level economic growth and, for agriculture, national production increases may overlook the goal of equitable growth and an emphasis on the poor majority. This concern is partly based on a lack of data conclusively showing links between policy reforms and increases in production and income among resource-poor agriculturalists. It is also a function of growing evidence of negative impacts that structural adjustment policies can have on the poorer segments of society. Assumptions that policy reforms can be effective in bolstering production without, among other things, addressing technical or infrastructural bottlenecks are also being challenged. In sum, questions are increasingly being raised regarding the wisdom of pursuing macro-level reforms on a broad scale without adequately understanding their impact at the micro-level (see ch. 6).

Another criticism of current implementation of Policy Reform is that it is not creating African capacity to implement and maintain such reform. This lack of attention to African capability contradicts the original conception of the Accelerated Development approach, with its stress on donor support for such activities (38).

The failure of the New Directions and Policy Reform approaches to address the technical and institutional needs of African agricultural development led to an approach to accelerate food production growth, detailed by the International Food Policy Research Institute (IFPRI). The IFPRI approach is based on the theory that increases in food production will lead to increases in farmer income which will in turn lead to increases in production and employment in other sectors of the economy.

Improved technology is seen as the driving force for speeding growth in food production. And national economic growth will depend on the commercialization of smallholder production, needed for the adoption of improved technology. According to this strategy, resources should be directed to: 1) fertilizer distribution, 2) agricultural research, 3) education and training, and 4) infrastructure development. Policy reform is an important but not primary goal and reforms emphasized are those that address these four areas.

The IFPRI strategy seeks to build African capability necessary to carry out development as it supports the implementation of these four factors. For example, indigenous fertilizer distribution systems and African analytical ability to set regional fertilizer priorities and import/distribution policies would be improved along with increases in the distribution of fertilizer. To support agricultural research, the approach emphasizes building and improving African research institutions. Increasing and improving human resources is part of building these African research institutions as staff must be trained to use and manage them. In addition, formal education for farmers would be increased so farmers could avail themselves of the services of agricultural institutions. Finally, improved rural infrastructure would benefit African transport and marketing capability and would require the involvement of local governments and rural organizations because of construction costs and maintenance needs.

The IFPRI strategy argues that donor assistance should be aimed at better-off areas that can take most advantage of the scarce development resources available. This means focusing on higher income small farmers who can invest in new technology and on geographic areas with favorable rainfall and soils or where soil problems can be solved. For commodities, this means limiting the majority of internationally supported research to a small set of widely grown, staple crops, such as maize, rice, sorghum, and cassava, that have the possibility for major improvement, especially in the higher potential geographic areas.

For many, the IFPRI approach, like Policy Reform, raises concerns over equity. Focusing assistance on the better endowed regions will bypass large numbers of Africans and contribute to increasing inequalities in income. Bypassing large numbers of persons also reduces the positive impact better-off agriculturalists have on stimulating economic growth since fewer people will be in this group (8). In addition, ignoring the less well-off regions will lead to ignoring the unsustainable production now taking place there and degradation of the natural resource base will continue.

These three approaches have been developed to address constraints to agricultural development: New Directions with lack of equity; Policy Reform with unsupportive national policies for agriculture; and IFPRI with a lack of technology and institutional support. A resource-enhancing approach combines parts of each of these three strategies to address the needs and abilities of resource-poor agriculturalists. For this reason, a resource-enhancing approach overlaps with each on specific points but also has significant differences.

A resource-enhancing approach shares New Directions' emphasis on equity because both address development of the majority of the poor although New Directions is broader because it also addresses the urban poor. Also, a resource-enhancing approach concentrates on increasing the productivity of the poor, versus New Directions' provision of basic needs—giving the former a more technical and institutional orientation. Provision of basic education, health care, and food, while complementary to a resource-enhancing approach, is peripheral to it.

Policy Reform's identification of the importance of supportive national policies is built into this resource-enhancing approach. Technologies and institutions' effectiveness can be greatly reduced by discriminatory policies. Unlike Policy Reform, though, a resource-enhancing approach would link reforms in policies primarily to the development of resource-poor agriculturalists. Therefore, action on such reforms would stress: links to the on-the-ground working of the agricultural sector, ensuring that benefits are received by a majority of resource-poor agriculturalists; providing "safety nets" for the poor significantly hurt by reforms; and providing significant attention to building African capacity to create and implement such reforms in order to ensure the two above points and the sustainability of the reforms. Policy reforms remain important in a resource-enhancing approach but less so than in a Policy Reform approach as resources must be used to support technical and institutional needs as well.

A resource-enhancing approach incorporates many of the components of the IFPRI approach. Both place strong emphasis on the need for improved technology, and both include the need for ensuring that technologies address the real constraints faced by farmers and herders through means such as on-farm testing of technology and farming systems research. In addition, both emphasize the need for institutional development to develop and support improved technology. This leads to a common emphasis on building African capability to carry out this work.

However, significant differences exist between the two approaches. A resource-enhancing approach would not direct assistance to only those agriculturalists and areas with high potential for improvement. It would address wider populations and geographic areas for reasons of equity and to prevent a large majority of resource-poor agriculturalists from being bypassed by development. This leads to different technological choices because the appropriateness of a technology depends, in part, on the resources available to an agriculturalist. For example, a resource-enhancing strategy would support the use of commercial fertilizers where applicable. However, it would not give them the same overall emphasis as the IFPRI strategy because significantly expanded use of purchased fertilizers is not affordable nor available to a large proportion of resource-poor farmers. Also, a resource-enhancing approach would support research on a broader range of agricultural commodities. Although some of these make up a comparatively small percentage of total agricultural production, they are often essential to household nutrition and income, and existing technologies could be adapted to improve their production. Addressing this concern would stretch research resources; therefore, greater emphasis is placed on developing national research capability and linking researchers, extension services, and agriculturalists in the most productive way. At the same time, a resource-enhancing approach places greater emphasis on slowing degradation of the natural resource base, much of which is occurring outside higher potential areas.

A resource-enhancing approach is apt to support small, evolutionary gains in production, placing greater emphasis on using available resources (e.g., technologies and local organizations). Where favorable factors of production (e.g., climate, soil, markets, research capabilities) exist, the IFPRI approach may be more relevant for local agricultural development. Although both approaches stress the formal training and development of institutions necessary for agricultural development, a resource-enhancing approach gives greater emphasis to linking this training and institution-building to the needs of low-resource agriculture. Resource-poor farmers and herders themselves play a larger role in a resource-enhancing approach via contributing knowledge, taking part in research, and working through their own organizations.

AFRICAN PERSPECTIVES

OTA solicited the thoughts of individual African colleagues concerning the relevance of its work on low-resource agriculture to African agricultural development.[4] The overall response was that OTA's approach to enhancing low-resource agriculture fit within their own conceptions of African agricultural development and this approach would be a realistic one for solving African food deficits. Several points were stressed:

First, the importance of the diversity of African agriculture was reiterated. All of the countries have problems but some face an agricultural crisis. The causes of these problems vary from country to country; and solutions also will vary. For this reason, development assistance needs to be flexible so that it can address local problems and develop an appropriate mix of responses. Promoting a single technique, such as adjusting pricing policies, with equal vigor across the continent was seen as a mistake. In order to have the necessary flexibility, donors would need to increase the decision making authority of their in-country personnel.

Second, increasing African capability was seen as essential. This could be carried out by increasing support for education and training, institutional support including core funding especially for research, and support for local organizations. In addition, donors should reduce their dependence on expatriates; increase their use of Africans; and give Africans more control and participation in project and program design, management, and evaluation.

Third, a need exists to work with the resources and technology available to the majority of the agriculturalists. Making use of traditional knowledge will be part of this work and technologies and institutions that can support traditional systems of farming are necessary. Farmers' knowledge and participation should be incorporated into the work and women should be actively involved. Technologies will need to support sustainable productivity.

Fourth, the nature of this approach means that assistance must be long term and have development as its goal. Levels and types of assistance should not be decided along political lines.

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[4] OTA surveyed some 40 African researchers and policymakers (app. C) for their views on: the state of agriculture in their region, how their views differ from those of donor agency personnel, how appropriate is OTA's model of low-resource agriculture, and what would be a constructive U.S. foreign assistance program for Africa. Their views were synthesized in: Hussein Adam, "African Perspectives of Low-Resource Agriculture," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).

Photo credit: P. Johnson, U.N. Food and Agriculture Organization

Photo credit: F. Mattioli, U.N. Food and Agriculture Organization

Photo credit: F. Botts, U.N. Food and Agriculture Organization

Africans stressed the need for U.S. development assistance to match Africa's diversity, to ensure that Africans' capabilities are increased, to build on the resources that the majority of agriculturalists have available to them, and to be committed to a long-term effort with development its most important goal.

Included with their general agreement with the approach of enhancing low-resource agriculture were several caveats. There was concern that any approach not become the sole strategy for agricultural development. Instead it should be carried out in conjunction with other approaches, such as increasing non-farm employment and improving rural people's health and education. The approach should not become subsistence-oriented but aim toward increasing the practice of science-based agriculture. Also, when carrying out the approach it should be remembered that some traditional practices will restrain agricultural development and should be discarded.

A small minority of responses strongly disagreed with an approach to enhance low-resource agriculture. Fears were expressed that it would lead to a class of farmers trapped at the subsistence level. In some cases, traditional systems were seen as impediments to development. And concern existed that the United States was incapable of carrying out a resource-enhancing approach because of U.S. emphasis on top-down approaches and providing food aid.

An additional issue raised by the respondents was the need to address corruption and the misuse of assistance. Where corruption is prevalent, the need to ensure the use of funds for development purposes should override the need for African management of funding and donor agencies should retain spending control.

Throughout the responses ran the call to consult with Africans before carrying out development assistance. This was expressed directly in respondents' specific comments and indirectly in the tone of their letters. Many expressed surprise and pleasure that the United States Congress had sought their opinions.

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Chapter 5

The Role of Technology in Enhancing Low-Resource Agriculture

CONTENTS

Page

Highlights 99
Technology's Place in a Changing Africa 100
What Is a Promising Technology? 103
Improving the Effectiveness of Technical Assistance to Resource-Poor Farmers, Herders, and Fishers 105
Technical Potential for Enhancing Low-Resource Agriculture 111
  Difficulties in Evaluating Technical Potential 111
  High Potential for Adoption 111
  Potential To Modernize Gradually 112
  Technology-Specific Potentials 112
Chapter 5 References 117

Boxes

Box *Page*

5-1. The Green Revolution and Africa 101
5-2. Farming Systems Research 108

Tables

Table *Page*

5-1. Promising Technologies and Practices by Agroecological Zone 103
5-2. Economic Analysis of Farmer-Managed Trials of Sorghum With Fertilizer and Tied Ridges at Nedogo and Diapangou, Burkina Faso in 1983 and 1984 113
5-3. Effect of Improved Practices, With and Without Fertilizers, on Crop Yields. 114
5-4. Gains From Improved Management Practices 114

Chapter 5

The Role of Technology in Enhancing Low-Resource Agriculture

HIGHLIGHTS

- Many agricultural and environmental problems facing Africa reflect a failure of traditional systems to accommodate the continent's rapidly increasing population. In most of Africa, the tradition of land-extensive, shifting agriculture will have to evolve into more intensive, permanent agriculture if food security is to increase. Technological innovation will play a major role in this intensification process.
- A technological approach with promise for promoting food security in Africa calls for an evolution of existing agricultural systems based more on sequential improvements in technology and incremental gains in productivity, as compared to the quantum increases in inputs and output that epitomize the so-called Green Revolution. Some high-potential areas in Africa will be able to follow the latter approach, but these areas are in a minority and Green Revolution technology will do little to address the needs of the majority of African agriculturalists who function under resource-poor conditions. A viable technological framework to assist low-resource farmers, herders and fishers should account for the following:
    - Successful development of Africa's highly diverse farming systems will require an equally diverse array of technologies adapted to local socioeconomic and environmental conditions. Although Africa will benefit from the fruits of global agricultural research, African problems will require increased emphasis on Africa-specific solutions.
    - Increased farmer participation in identifying problems and acceptable solutions could enhance the effectiveness of technical assistance. Existing farmer practices should be the starting point for integrating the best of traditional and modern technologies.
    - Technologies in support of low-resource agriculture should reflect the high premium this practice places on risk aversion and the need to maintain flexibility in the face of uncertainty and limited access to resources.
    - Resource-poor agriculturalists rely primarily on internal resources. Consequently, information for intensive management and other technologies should emphasize the use of internal resources also.
- Technologies that offer the most promise for contributing to the food security of resource-poor farmers and herders share common characteristics. These include technical and environmental soundness, social desirability, economic affordability, and sustainability.
- Promising technologies outlined in this report appear to be able to significantly improve Africa's future food security through improving the use of natural resources, increasing soil fertility and water availability, providing genetic improvements in crops and livestock, improving integrations of animals into cropping systems, and reducing food losses and workload. However, technologies do not operate in isolation and non-technical factors will heavily influence the extent to which this technical potential is realized.

TECHNOLOGY'S PLACE IN A CHANGING AFRICA

Technological innovation in low-resource agricultural systems will be a major factor contributing to Africa's ability to meet the challenges ahead. However, technical solutions alone will not solve Africa's food security problems.

Throughout the world, agricultural systems have met increasing food needs by intensification, and technology has always played an important role in this process. Through more active management and application of technology and other inputs, it becomes possible to expand and accelerate agricultural production beyond that possible by relying on natural processes alone. However, much crop and livestock production in Africa is extensive rather than intensive. A small percentage of African food production is likely to remain extensive where population densities are still low, or where people have settled in new lands opened by disease control, for example. In areas like these, shifting agriculture historically has been an ecologically sound and labor-efficient means of producing food. In fact, until recently, shifting agriculture was sustainable in much of Africa because fields could be cultivated for perhaps 5 years in semi-arid zones or 1 to 3 years in more humid areas, and then allowed to lie fallow for 10 to 15 years to restore the land (42,47,50). As populations increased and as land became more scarce, however, this age-old agricultural method began failing. As fallow periods shortened, yields have declined, additional marginal land has been put into production, and environmental degradation has accelerated (45).

Livestock production faces a similar situation, particularly on Africa's rangelands. Indigenous systems have developed to use scarce, often unreliable, natural resources efficiently. Recent studies show these systems to be much more efficient than previously believed (3,15). Yet it is evident that in more and more cases, traditional practices are no longer sustainable. One contributing factor is the increased numbers of pastoralists and livestock. Perhaps more detrimental, however, is the increasing conflict over land and resources as farmers extend further into rangelands and as pastoralists are forced onto rangeland of marginal productivity and lose access to critical dry-season forage (27).

Declining per capita food production and income, as well as serious degradation of the resource base on which African development depends, provide compelling evidence that resource-poor farmers, herders, and fishers will require additional technology and technical assistance to intensify their agriculture. The rate at which intensification will need to take place, or even the extent to which intensification is possible, obviously varies greatly in a region as diverse as Sub-Saharan Africa.

But what form should technical assistance take? A review of the disappointing results to date suggests that technological interventions often overemphasize solutions imposed from the outside. These commonly fail to consider local perceptions and social and environmental conditions, and tend to underemphasize more integrated approaches to problem-solving (51,52).

The prospect that Africa will need to double its agricultural production over the next few decades to keep pace with population growth is daunting. It also has given rise to the notion that nothing short of a Green Revolution approach for Africa, such as the one that transformed much of Asia's agriculture, will meet this challenge. Certainly a few areas of Africa, notably the regions with high agronomic potential and well-developed infrastructure, have benefited from technology developed in Asia, but it seems unwise to expect a Green Revolution strategy to be widely applicable to Africa in the foreseeable future (box 5-1). In comparison to those parts of Asia that benefited from the Green Revolution, Africa has poorer soils and less water available for agriculture; lower labor/land ratios; less developed human and institutional infrastructure; and it relies on not one but several staple crops, most of which have short research histories (4).

Box 5-1.—The Green Revolution and Africa

When people talk about African agriculture, they often compare the continent and its problems to India in the mid-1960s, when that country faced massive food problems, was heavily dependent on emergency food aid, and was often written off as a "basket case." If India can make the progress it has—and today India is exporting food, including food aid to Africa—why can't Africa? The answer is simple, although the context is complex: Africa and India are two very different places and some of the most useful lessons from the Indian experience are drawn from highlighting those differences.

Climatic and Physical Differences

The dramatic gains in Indian agricultural output occurred largely in the Punjab, an area with relatively fertile soils, a geology that permitted the widespread adoption of irrigation, and few pest problems. The high-yielding varieties of the Green Revolution were bred to perform best under such conditions. In contrast, African soils are generally low in fertility. They tend to be shallower, have poorer texture, are more inert, and have lower water-holding capacities than comparable Indian soils (32). Also, African geography is less conducive to irrigation, especially large-scale projects. In Africa, only 3 to 5 percent of cultivated areas are irrigated whereas at least 20 percent of Indian's cropland is (11,55).

In Africa's high-rainfall areas, agricultural production is limited by low sunlight, rapid leaching of soil nutrients, soil degradation when crops are removed, and the rapid spread of pests and diseases. Production in semi-arid areas is limited by lack of rainfall. West Africa's semi-arid areas tend to have shorter growing seasons with greater risk of drought than the semi-arid areas in India with similar levels of rainfall. This suggests that shorter growing-cycle crop varieties are needed and these are generally more risky.

Crop Differences

Rice and wheat, the predominant Green Revolution staples in India, have a long history of scientific research. Also, the environmental conditions of the Punjab allowed India to introduce improved varieties and adapt them quickly to local conditions. The successes with rice and wheat were partly a function of plant breeders' ability to develop photo-period insensitive varieties that could be adopted over a wide geographic area. No such varieties seem to be on the horizon for millet, sorghum, or the other 10 main staple crops in Africa. For example, there has been little success in introducing improved Indian sorghum and millet varieties into West Africa because of disease and pest problems, and water control problems have prevented the introduction of dwarf rice varieties. Only 2 imported rice varieties of 2,000 tested performed as well as local varieties in 10 years of experiments. Modern crop breeding research has begun only recently for other African staples, such as roots and tubers.

Economic Differences

The spread of new varieties in India was fostered by a better transportation network and more highly integrated markets for inputs and crops than exist in Africa (21). Another important difference is that while India is a large, relatively closed economy, African economies are typically small and depend heavily on foreign trade. Indian political leaders could make the decision to concentrate agricultural research on one high-potential region (the Punjab). This type of decision is politically difficult if several countries are involved. Moreover, small countries may not have the critical mass of scientists to support agricultural research, but multi-country regional research is often difficult to coordinate. Open economies are more susceptible to fluctuations in international prices, especially for their main export prices. Government revenues, and hence, agricultural research budgets, depend on export earnings and are highly unstable as a result.

The relative prices of land and labor are also quite different between Africa and India. In India, land is scarce, while labor is abundant. Consequently, agricultural technologies were developed to be land-augmenting and labor-using. In Africa, seasonal labor bottlenecks and highly variable rainfall are major constraints, while labor is abundant at other times of the year. Hence, Africa's pressing agricultural needs include technologies to relax these constraints, such as selective mechanization and plant varieties that are bred for yield stability. As population pressures increase, however, the need for more land-augmenting, labor-using technologies will increase.

(continued on next page)

Differences in Human Resources

A key factor in India's success in agricultural research was the heavy prior investment that the country had made in human capital and in developing the research and training institutions that then generated both trained scientists and knowledge about the country's agriculture. India began building colleges of agriculture in the 1920s under the British colonial government, so by the 1960s Indian policymakers and scientists were very knowledgeable about the nature of the problems facing agriculture in that country, where the highest payoffs to research were likely to be, and which parts of the country had the greatest agricultural potential. This knowledge was then used to focus domestic and foreign assistance research efforts.

In contrast, African countries have until recently devoted little investment to training agricultural scientists or building research institutions. The lack of trained personnel and knowledge of local agricultural conditions in much of Africa severely limits the effectiveness of foreign assistance and places too much reliance on expatriates. Also, Africa has yet to develop an educated lobby for agricultural policymaking such as emerged in India in the 1960s.

Lessons for Africa

The Indian experience shows that progress in overcoming food problems in poor countries is possible, but that it is a long-term process that depends not so much on importing new technology from abroad, although that may be important, but on developing indigenous capacity in the agricultural sciences and in policy analysis. These skills allow a country to borrow judiciously from abroad and adapt foreign technologies to local conditions, as well as to develop new technologies locally. Developing this knowledge and scientific capacity in Africa is a long-term process; without such capabilities the effectiveness of foreign technical assistance is likely to remain low. But India's experience shows that technology itself is not enough. Supporting institutions are extremely important also.

SOURCE: John M. Staatz, "The Potential of Low-Resource Agriculture in African Development," contractor report to the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).

This is not to suggest that the situation in Africa is hopeless. Some technical progress is being made that justifies cautious optimism. However, rather than relying on the relatively homogeneous package of technologies and inputs that produced a dramatic Green Revolution in Asia, more viable approaches for promoting food security in Africa call for evolution of Africa's existing farming systems. An approach suited to enhancing African low-resource agriculture involves sequential improvements in technology that provide incremental gains in productivity, as well as greater stability of production. The technological framework entails a more diversified approach whereby technologies are better suited to the needs and characteristics of Africa's wide range of small-scale, resource-poor farming systems.

Much uncertainty surrounds the issue of the availability of technologies for this task. Some experts feel that domestic and international researchers "have not produced a large enough stock of technological innovation capable of ensuring sustainable growth in aggregate agricultural output" (43). Others believe that the necessary technologies exist, and the problem is their poor adoption rates. This uncertainty reflects, in part, an imbalance between the emphasis given to research at the experiment stations and the relative neglect of on-farm, adaptive research. The people working more closely with farmers and herders seem less optimistic regarding availability of suitable technology.

While OTA's analysis suggests that certain types of technical interventions can help improve food security significantly, it would be irresponsible for donors to place all their African agricultural development eggs in one basket. Successful approaches will be a thoughtful, integrated approach—a mix of objectives and programs reflecting the diversity that exists in Africa—but technical assistance certainly will need to address low-resource agriculture more than it has in the past. The following sections provide a general framework and present specific findings regarding technology's role in improving low-resource agriculture. The chapter concludes with a general discussion of the overall potential of technology to promote improved productivity and sustainability of low-resource agriculture.

WHAT IS A PROMISING TECHNOLOGY?

One of the most important lessons to arise from past development assistance failures is that to be successful, technical interventions must match the specific constraints shaped by local social and environmental conditions. How, then, can OTA speak of promising technologies for the whole continent of Africa? First, OTA classified Africa into four agroecological zones based on the U.S. Agency for International Development's refinement of the United Nations' Food and Agriculture Organization (FAO) work on Africa's soils, climates, and crops. Then OTA consulted development experts familiar with each of these zones to identify technologies that they believed held the most promise for increasing the availability and stability of locally produced food. These consultations included a telephone survey, Advisory Panel meetings, two workshops, and production of a series of background papers on individual technologies (app. A, B).

Table 5-1 summarizes the specific promising technologies addressed in this report along with their geographic applicability and their primary benefits. Each of these technologies is appropriate for application in certain agroecosystems at particular times. An important criterion in choosing these technologies is their compatibility with the nature of low-resource agriculture and the guidelines for effective development assistance presented in chapter 4. A close match suggests a high probability that they will be accepted by low-resource farmers and herders and that they can be used effectively.

Technologies that offer the most promise for contributing to the food security of resource-poor farmers and herders share common characteristics, including:

- *Technical and environmental soundness*: This means they are able to stabilize, if not increase, production while ensuring conservation of natural resources.
- *Social desirability*: This means technologies must address farmer-identified problems and constraints. In addition, they should attempt to minimize the disruption of existing farming systems.
- *Economic affordability*: This means that resource-poor farmers, herders, and fishers must be able to obtain and maintain the

Table 5-1.—Promising Technologies and Practices by Agroecological Zone[a]

Technology and practices	Zone[b]	Primary benefits
Improved use of soil and water resources		
Soil and water management		
Recession farming	A,S,H	Labor-efficient method of growing crops using water from annual floods; expands area under cultivation
Water harvesting microcatchments	A,S	Increase water available from rainfall
Planting and building bunds on the contour	A,S,H,T	Increase water available from rainfall; reduce soil erosion
Tied ridges	A,S	Increase water available from rainfall
Drainage practices	H,T	Enable production on land that would otherwise be waterlogged
Terracing	T	Reduces water and soil runoff; enables cultivation on steep slopes
Minimum tillage, mulching and other soil-conserving vegetation practices	S,H,T	Prepare land without incurring costs of plowing (soil erosion, excessive leaching and compaction); organic residues and mulch help maintain fertility, reduce water and soil runoff

Table 5-1.—Promising Technologies and Practices by Agroecological Zone[a]—Continued

Technology and practices	Zone[b]	Primary benefits
Improving soil fertility		
Biological nitrogen fixation . . .	A,S,H,T	Increases nitrogen availability
Vesicular-arbuscular mycorrhizae	A,S,H,T	Increase phosphorus availability
Manuring	S,H,T	Increases soil organic matter and soil fertility
Phosphate rock	A,S,H,T	Increases phosphorus availability
Commercial fertilizers	A,S,H,T	Increase soil fertility
Small-scale irrigation		
Gravity diversion: channeled systems	A,T	Increase water availability
Gravity diversion: poldered systems	A,S,H	Increase water availability
Mechanically fed: water lifting	A,S	Increases water availability
Mechanically fed: water pumping	A,S,H,T	Increases water availability
Improved cropping practices		
Intercropping	A,S,H,T	Reduces risk of crop failure; increases seasonal availability of food; reduces pest and disease problems; improves efficiency of resource use
Home gardens	A,S,H,T	Increase seasonal availability of food; improves nutrition in the diet
Agroforestry		
Dispersed field tree intercropping	A,S	Increases soil organic matter; provides source of fodder, fuelwood, poles
Alley cropping	S,H,T	Increases soil organic matter; provides source of fodder, fuelwood, poles
Windbreaks	A,S,H,T	Decrease wind damage, especially to seedlings; decrease evapotranspiration; provide source of fodder, fuelwood, poles
Live fencing and other linear planting	A,S,H,T	Provides source of fodder, fuelwood, poles, fencing
Genetic improvements		
Crop breeding	A,S,H,T	Provides resistance to diseases and pests; tolerance to environmental stress; improves yield
Animal breeding	A,S,H,T	Provides resistance to diseases and pests; tolerance to environmental stress; improves yield
Improved use of animals		
Mixed crop/livestock systems using small ruminants	A,S,H,T	Increase income; improve diet; reduce risk through diversification
Animal traction	A,S,H,T	Reduces drudgery; improves labor productivity; extends area of cultivation
Aquaculture	A,S,H,T	Provides source of protein; recycled nutrients; source of income
Improved systems to reduce pest-loss		
Integrated pest management		
Quarantines	A,S,H,T	Reduce risk of accidental introduction of pests
Host resistance	A,S,H,T	Improves resistance to pests and disease
Cultural controls	A,S,H,T	Reduce pest populations by manipulating farming practices, especially by intercropping and rotating crops
Biological controls	A,S,H,T	Reduce pest populations by using natural enemies
Pesticides	A,S,H,T	Reduce pest populations by using natural or synthetic biocides to kill pests, limit their fertility, or disrupt pest development
Post-harvest technologies	A,S,H,T	Improve processing and storage of foods; improve nutrition; reduce labor
Improving animal health		
Veterinary support	A,S,H,T	Reduces animal mortality and morbidity
Animal nutrition	A,S,H,T	Increases productivity; improves feed use efficiency; reduces susceptibility to disease

[a] See box 3-4 for a map of Africa's agroecological zones.

[b] Key to agroecological zones: A = Arid/Semi-Arid, S = Subhumid Tropical Uplands, H = Humid Lowlands, T = Tropical and Subtropical Highlands.

SOURCE: Office of Technology Assessment, 1988.

technologies. In Africa, this generally means a need to use resources internal to the farm rather than externally purchased inputs.

- *Sustainability*: This means that technologies are environmentally, socially, and economically feasible to maintain in the long term. Especially given Africa's rapidly increasing populations, this requires technologies that enable farmers to take additional steps toward modernization as they become feasible.

IMPROVING THE EFFECTIVENESS OF TECHNICAL ASSISTANCE TO RESOURCE-POOR FARMERS, HERDERS, AND FISHERS

Chapter 4 outlined four concepts important to enhancing low-resource agriculture. These concepts have implications for selecting, developing, and disseminating technology. Also, OTA derived findings from the detailed information on technologies in chapters 7 through 11 and the 16 contractor reports on technology on which those chapters are based (app. A.) These findings, then, represent common threads and conclusions gleaned from this various material.

Finding 1: **Technologies do not operate in isolation and they are affected by non-technical as well as technical factors. A systems approach to agricultural development would consider how national level decisions on issues such as fixed crop prices, land tenure, and incentives for conservation, affect farm level decisions, and it would consider potential interactions among social, economic, and environmental factors on the farm.**

A variety of national-level decisions affects low-resource agriculture. Technical assistance to low-resource agriculture will be more successful if national governments have the capacity and inclination to provide support for the process. Economic considerations such as ensuring adequate prices and affordable inputs for producers can act as important incentives in determining whether resource-poor farmers, herders, and fishers will find it in their interest to increase productivity by investing in new technology. In Zimbabwe, for example, the government set favorable grain prices and provided farmers with access to credit, extension, inputs, and markets. Small-holder farmers responded by tripling their maize production between 1980 and 1985, when it reached 1.6 million metric tons—50 percent of Zimbabwe's total production (41).

Secure land tenure and conservation policies are two critical non-technical factors operating at the national level that affect the adoption of several technologies discussed in this report. For example, mulching and other soil-conserving practices often have an immediate expense to the herder or farmer: foregone fodder and/or land that could have been used for crop production. These methods have little chance of success unless a commitment exists at the national level to conserve soil and water resources, and some assurance to the individuals who bear the costs that they will share in the long-term benefits. As it happens in developed countries, developing country governments will need to provide incentives encouraging conservation measures so the entire burden is not borne by individual farmers and herders (26).

Social, cultural, and economic factors at the household level also determine the acceptability of a particular intervention. For example, developing crop varieties capable of dramatically increasing total yields serves little purpose if the varieties are not acceptable because of taste preferences, cooking quality, or storage requirements. The relative success of hybrid maize in Kenya and Zimbabwe, compared to the low adoption rate in Malawi, illustrates this need for a holistic view. Farmers in Kenya and Zimbabwe have taken advantage of the increased yields of hybrid maize to make it their major cash crop. In Malawi, however, women farmers prefer local varieties of maize because of easier production and better taste. Adapted hybrids with these traits are not yet available.

Higher yields are advantageous, but secondary to these other considerations (36).

An understanding of farming household dynamics and divisions of labor—especially the key role of women—is particularly necessary when developing and promoting technology for low-resource agriculture (2,34). An urgent need exists for technologies that address women's labor constraints, yet the topic remains under-researched (8). Many cases can be found where technological innovations for women's work have excluded women, instead channeling information through male household members to the detriment of the technology's effectiveness (5,23,44).

Successful adoption of a specific technology normally will require changes throughout the farming system. For example, a small-scale irrigation scheme may only be economically feasible if there is an increase in the amount of land cultivated. This additional land could be prepared using animals, but introducing animal traction commonly requires prolonged extension efforts and may require credit that is not available. The cost of maintaining animals can be partially offset by recycling manure, but this may depend on developing improved ways of storing and transporting manure. Cultivating additional land may cause labor shortages when weeding must be done despite the use of animals; then judicious use of herbicides may be warranted. Likewise, the economic feasibility of an irrigation system could be increased by the development of farmer cooperatives. Collectivization of this sort involves its own set of repercussions. This scenario explores only a few of the many possible changes that could accompany the introduction of an irrigation scheme, but the example illustrates several points:

- Technologies are often compatible with one another—in fact, they may produce larger gains together than would be expected on the basis of the benefits of single methods.
- To make adoption of a particular technology feasible, it must sometimes be "packaged" with other technologies. However, past development efforts often failed because they presented "all or nothing" packages. Farmers unable or unwilling to adopt the entire package were not able to take advantage of a single component.
- Alternative packages consisting of various combinations of technologies are promising, allowing enough flexibility for farmers to decide which technologies to combine. Furthermore, at least some of the benefits of the package must be available immediately; they can then be used to carry the costs of the longer-term components (6).

The fact that any individual technical intervention affects, and is affected by, numerous outside factors suggests that a systems approach has the best chance of being successful. Development assistance could benefit by recognizing and planning for interactions among the various components of the agricultural system. At the same time, planners must be careful to avoid the weaknesses shown by past integrated rural development projects that attempted to be so all-encompassing that they became unmanageable.

Finding 2: **To be successful given the great diversity in African farming systems, an equally diverse array of technologies adapted to local social and environmental conditions needs to exist. Although Africa will benefit from the fruits of global agricultural research, African problems will require greater attempts to develop Africa-specific solutions.**

The tremendous diversity and variability in African agricultural systems is among the most challenging obstacles to technology development in Africa. Although some successes exist in promoting technologies developed outside Africa, such as the high-yielding varieties of corn that have been successfully introduced into East Africa (19), failures abound. Efforts to introduce Indian varieties of sorghum and millet into West Africa largely have failed, and after 10 years of testing at least 2,000 imported rice varieties in the mangrove swamps of West Africa only 2 have been found that perform as well as the best local varieties (29,43).

On the positive side, the diversity of farming systems represents a set of practices and resources that have evolved to meet unique local opportunities and constraints. These adapted, local practices and varieties represent a wealth of resources and information. To draw on this wealth, however, requires increased local participation. Three approaches could contribute to increased local participation:

1. Increasing African Research Capacity Through Human and Institutional Development.—Expatriate expertise may be necessary under certain circumstances, but replacing outside expertise with trained African professionals should be an explicit objective of development assistance. It costs several times more to fund a non-African v. an African scientist in Africa given similar salary levels. Also, non-Africans take much of the knowledge of the development process with them when they leave. Therefore providing counterpart training to ensure that host country capability is developed should be a prominent objective when outside technical expertise is used. While this is a stated goal of much development assistance, in fact, expatriates play a large role in many African countries (10).

2. Improving the Links Among Researchers, Extension Agents, Farmers, and Herders.—The traditional top-down approach where technologies are developed at research stations and distributed to farms has been largely unsuccessful in Africa. Part of the problem is due to inadequacies in the extension system, but much of the failure results from attempts to distribute technologies that are not appropriate for resource-poor farmers, herders, and fishers. Improving information flow from the people to extension agents and researchers increases the likelihood that development of technologies is suited to low-resource conditions. However, even these more acceptable technologies will require improved extension systems. The ratio of extension agents to farmers, reported to be 1:3,000 for the arid and semi-arid zone of West Africa, should be increased to 1:500 to 1:1,000 according to some estimates (19,53). One possibility would be to model an agricultural extension system after the pyramid training system used in Burkina Faso to improve health care dramatically. There, a few national experts train regional trainers, who train district trainers, and so on to the village level (19). Ensuring two-way dialog in this process, as in any other extension system, should be a priority.

3. Giving Increased Emphasis to On-Farm Adaptive Research With a Farming Systems Perspective.—Initial development and preliminary field testing of a technology can benefit from the controlled conditions of a research station or closely supervised farm. However, resource-poor farmers face less than ideal conditions and adaptive research should be conducted on-farm as early as possible (box 5-2). The potential rewards available from on-farm research are substantial. Certain challenges will have to be faced, however, including:

- The high variance in environment and management present on-farm require more detailed interviews and more frequent and timely visits by the researcher compared to on-station research.
- Efforts must be made to help farmers improve their understanding of the experimental nature of the work so that farmer bias, for example, putting more labor into the trials than traditional fields, will decrease.
- Field staff must be willing to live under the less favorable conditions of the village and be able to operate with less supervision than at the research station. An incentive system that compensates for living and working conditions off-station may be necessary (31).

Finding 3: **Farmer and herder participation in identifying problems and acceptable solutions would enhance the effectiveness of technical assistance. Existing agricultural practices could be the starting point of a process combining the best of traditional and modern technologies.**

Encouraging agriculturalists to participate in the development of agricultural technology is a way to improve the chances that innovations

Box 5-2.—Farming Systems Research

Farming Systems Research (FSR), as used in this report, refers to an approach to agricultural research and extension that emphasizes social and economic factors in addition to technical factors, including those that operate on the farm and those that are outside of, but affect the farm.[1] **FSR is an approach to, and not a substitute for, conventional agricultural research. It developed and continues to evolve in order to enhance the effectiveness of agricultural research, particularly in reaching resource-poor farmers.** Numerous factions exist that can be considered under the FSR rubric, but most practitioners agree that the approach relies heavily on farmer input into four stages of technology development and diffusion: (38)

1. an iterative process for diagnosing needs, problems, and constraints in the farming system;
2. identifying priority problems, analyzing proposed solutions, and developing field trials to test proposals;
3. farm-level experimentation, including monitoring, modification, and verification of proposed solutions; supportive on-station research; and evaluation of adoptability; and
4. dissemination of farmer-approved results to relevant groups of farmers.

Agricultural research and extension is more effective when an FSR component is included, but there is a cost to using FSR to support conventional research. Sociological data, for example, on intra-household dynamics and gender issues, must be collected. Anthropologists, sociologists, and economists are hired to complement the agronomists, plant breeders, and others to form multi-disciplinary teams. Some of this expense may be reduced in the future as agronomists and other natural scientists receive training to incorporate social science perspectives more effectively into their research methodologies. There are also expenses associated with farmer participation and on-farm trials. Meaningful cost/benefit analyses do not exist yet for FSR. This is not unusual for a relatively new discipline, especially given the time-lag for the effects of agricultural research. More problematic is that as an adjunct to conventional research, FSR is difficult to evaluate independently. Many of the benefits, such as greater sensitivity on the part of researchers to the disadvantaged members of a target group, are not easily quantified.

OTA's analysis suggests that the principles embodied in FSR will be an essential component of any strategy to improve food security. This is especially true in Africa, where failure to take into account non-technical factors, such as labor bottlenecks and shortages, has repeatedly thwarted attempts to introduce technologies (33). An approach like that of FSR will be a valuable tool in helping to mitigate such factors, as well as in identifying gender, age, ethnic, and class differences that affect development assistance.

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[1] "Farm" is used broadly to refer to the site of plant or animal production.

will be useful and acceptable and minimize the costs and time necessary for development of adapted technologies (31). Such a research partnership between scientists, farmers, and herders can be advantageous to all, as the following example illustrates.

The Variegated Grasshopper (*Zonocerus variegatus*) is a widespread crop pest of the wet areas of West and West Central Africa. Western entomologists undertook a study of the *Zonocerus* problem while parallel work was done to learn the extent of local knowledge concerning this pest. Farmers understood the pest well. In fact, several farmers interviewed had anticipated the main pest control recommendation of the research team: to mark and dig up sites where grasshoppers laid eggs. These local initiatives had not yet proven very successful because they had not been coordinated community-wide. Grasshopper numbers were reduced 70 to 80 percent when the extension service provided coordination. Some discoveries made by the research team were beyond the scope of the farmers because they required laboratory facilities; for example, work on the role of the grasshoppers' chemical attractants. On the other hand, information possessed by farmers— in particular on egg-laying behavior and possible correlations between insect population and rainfall—could have sped the scientists' initial efforts and made them more cost-effective (39).

Although researchers are becoming more convinced of the advantages gained from working with farmers and herders, problems remain. The following guidelines can facilitate this process:

- Include farmers and herders as integral comembers of interdisciplinary teams. Use language and units of measure that are meaningful to them.
- Make use of their nonformal experimentation and local knowledge of soils, indigenous varieties, pests, etc.
- Encourage agriculturalists to take an active role in experiments, including making modifications and conducting evaluations.
- Reach agreement with cooperating farmers about the responsibilities for, and opportunities of, each team member (31).

Even successful traditional technologies can be improved and this approach is generally preferable to substituting foreign methods. Moreover, new technological interventions, such as fertilizers, stand a better chance of acceptance if extension plans call for their use with familiar practices, such as intercropping (growing different crops together), rather than requiring people to switch to an unfamiliar and more risky practice (e.g., monocultural farming) at the same time.

Finding 4: **Technologies in support of low-resource agriculture should reflect the high premium this approach places on risk aversion and the need to maintain flexibility in the face of environmental, social, and economic uncertainty and limited access to resources.**

Farmers throughout the world are justifiably conservative in adopting new technology when its failure could mean bankruptcy or even starvation. Resource-poor farmers and herders operate in an environment characterized by a high degree of self-reliance; they depend largely on local resources, local knowledge, and labor provided primarily by the household. Although few agricultural systems can be described as entirely subsistence, a large part of what is produced by most households is consumed by their members. The importance of ensuring adequate food supplies, especially during unfavorable periods such as during droughts, becomes of paramount importance. Many practices characteristic of low-resource agriculture ensure at least some production in bad periods, even at the expense of less than maximum yields under more favorable conditions.

To date, most agricultural research and technology has emphasized maximum production even though numerous other concerns face poor farmers, herders, and fishers. Research priorities do not yet reflect diverse objectives such as minimizing risk, reducing drudgery, and matching labor demands with labor availability. For example, even though some 80 percent of African food is grown as intercrops, in part to reduce risk, only 20 percent of International Agricultural Research Center funding for crop research involves intercrops (1,54).

Finding 5: **Resource-poor farmers, herders, and fishers rely primarily on resources internal to the farm or their immediate environment. Consequently, technologies to support low-resource agriculture also should emphasize the use of internal resources as the first step in agricultural intensification. Thorough economic analysis is needed to determine the feasibility of all technological interventions, especially those requiring externally purchased inputs.**

One way to describe the resources used in agricultural systems is as "internal" and "external" (40). Those factors internal to the farm and immediate environment include sunlight, rain, nitrogen fixed from the atmosphere, nutrients cycled up from lower soil strata and down from plant and animal wastes, and labor. External resources include purchased fertilizers, pesticides, machinery, and fuel. Information becomes an internal resource even if it is originally supplied externally. Trade-offs between external and internal resources are possible. Scientifically designed agricultural systems that attempt to decrease dependence on purchased external inputs often substitute more intensive management based on information, for example, biological knowledge of soils, crops, and animals (14).

Photo credit: Mike McGahuey

Low-resource agriculture relies primarily on internal resources such as indigenous crops and locally adapted farming methods. For example, baobab and millet are native crops in Niger and growing them together is a common practice.

Low-resource agriculture relies largely on internal resources—many of which are renewable natural resources. By contrast, most agricultural development assistance to Africa has emphasized external resources—many of them costly and dependent on non-renewable fossil fuels. Strategies of technological intervention giving higher priority to internal resources would benefit the majority of farmers, herders, and fishers who cannot afford other options.

Family labor is one of low-resource agriculture's most valuable internal resources. Labor-efficient technologies to reduce the drudgery and overall workload, and especially seasonal labor bottlenecks, could substantially improve the lives of resource-poor farmers, herders, and fishers. Demographic, economic, cultural, and environmental factors are responsible for seasonal labor shortages (18,37) that are particularly detrimental when they result in late planting and insufficient and untimely weeding (13). However, technologies that displace labor from the rural areas may have additional adverse impacts. Most African countries do not have the industrial or non-farm employment needed to absorb rural labor.

The use of purchased inputs is feasible in several areas of Africa, and is an appropriate avenue for development assistance now. In the future, more farmers and herders can be expected to use purchased inputs, to have greater access to information, and to be better able to buy and sell their goods. While most farmers, herders, and fishers remain capital-poor, it is especially important that proposed interventions be submitted for careful cost/benefit analysis. More thorough economic analysis of all types of technologies should be an essential feature of assistance to people who already are living on the margin of survival.

Finding 6: Development of technology with built-in flexibility and adaptability is likely to most benefit a changing Africa.

African agriculture certainly will continue to change in the future. Strategies to improve low-resource agriculture should be designed to allow for these changes.

Development of technology that is flexible and adaptable is likely to most benefit a changing Africa. The ability to continue enhancing production is necessary to avoid stagnation of African low-resource agriculture.

Africa's rapidly growing population is one factor that will affect the future of agriculture. Another demographic shift affecting low-resource agriculture results from the disproportionate urban migration of young men in search of work. This migration creates a general trend toward an older rural population with implications for the structure of the labor force and has led to increases in the number of female-headed households. The latter is particularly important in light of the gender-based discrimination evident in areas of technology extension and credit (16).

TECHNICAL POTENTIAL FOR ENHANCING LOW-RESOURCE AGRICULTURE

Difficulties in Evaluating Technical Potential

The research literature on Africa is filled with promises of technological success. The International Institute of Tropical Agriculture has developed a sweet potato that can yield 40 mt/ha without fertilizers, at least six times the African average of 6.5 mt/ha (17). Windbreaks have been shown to increase crop yields, while supplying valued fodder and fuelwood. Yet the adoption rates for improved crops are very low, and freely supplied tree seedlings often go unplanted. Why? The answers range from farmer or herder unfamiliarity with the practice to researcher unfamiliarity with the farmer or herder—including researchers' failure to understand criteria used in rejecting the new technology.

Increased yields of 20 to 40 percent are typical for moderate fertilizer doses, or for plowing, or for improved land management. Yield responses of 100 percent in on-station trials are not unusual with all these improvements. Even greater increments can be attained by adding more input-responsive crop varieties. However, only a small proportion of farmers who apply these innovations approach the performance levels of experimental stations. Average yield gaps of 40 to 60 percent are normal, resulting in high risks of financial loss and low adoption rates for farmers (30).

Unlike the situation in the United States where experts can estimate increases in the national production of, for example, corn if fertilizer application is doubled, it is impossible to make a comparable continental or even national estimate for Africa. Africans' access to this input, ability to purchase it, and capability of using it effectively, are much more variable than for farmers and ranchers in developed countries. Estimates based on such a high degree of uncertainty in so many variables are problematic at best. They can be misleading and have a tendency to assume a life of their own, divorced from the caveats and cautions that originally framed them.

In some cases it is difficult, if not impossible, to use quantitative, rather than qualitative, criteria to evaluate a technology. Quarantines, for example, are intended to prevent accidental introductions of pests from outside the country. It is possible to estimate the costs incurred by a pest, such as the cassava mealybug introduced into Central and West Africa, when a quarantine fails. But methods do not exist to effectively quantify the savings that derive from successful quarantine programs.

Therefore the estimates of potential used in this report, and even the choices of technologies, are meant only to be illustrative. The technologies are not "the solutions" to Africa's problems, but are intended to suggest what might be accomplished using the approach to development assistance presented in this report. Where possible, technical benefits are evaluated based on actual use in fields, rather than at experiment stations. Rarely has OTA tried to extrapolate from these isolated examples to guessing the quantitative potential for an entire agroecological region. Benefits such as improving the stability of production have been given greater weight in this report than yield-increasing practices. Risk-aversion also has been used as an important criterion. Less emphasis has been placed on quantifying what the technology can accomplish in favor of discussing the logic of why that technology is an appropriate choice among the possible alternatives and what factors are involved in its success.

High Potential for Adoption

An important criterion in deciding which technologies can make significant contributions in Africa's future is its high probability of being adopted by resource-poor farmers, herders, or fishers. For the transfer of technologies to be successful, people must be willing and able to adopt them. Some technologies discussed in this report already are in use but are capable of improvement (e.g., intercropping). Other technologies are "new" but their acceptability is enhanced by the fact that they are well-matched to the needs and resources of low-resource agriculturalists. For example, many farmers recognize that declining soil fertility is a constraint but have found few alternatives to shifting cultivation for dealing with this problem. Many are learning the hard way that erosion hurts yields, dropping by 1 to 3 percent per year in some places (28). Alley cropping has shown potential for alleviating this farmer-identified problem. By combining scientifically based improvements for accelerating fallows with other benefits such as fuelwood and fodder production, alley cropping represents an affordable technology that addresses several farmer concerns.

Too often technologies have been evaluated on the basis of their technical qualities, with too little attention paid to whether they will, or can, be used. Furthermore, even when a technology has been used successfully in one case, its feasibility under different locale-specific conditions must be evaluated. For example, animal traction has been shown to be advantageous in Africa and could receive increased attention from development assistance. However, many animal traction technology packages require that new kinds of cattle be purchased and kept well-nourished and disease-free. The low adoption rate of this technology among resource-poor farmers will persist unless prerequisites to adoption are addressed—e.g., availability of forage supplies, veterinary care, and extension information about the benefits of unfamiliar types of animals.

Potential To Modernize Gradually

Another advantage of the technologies discussed in this report is that they do not lock people out of modern agriculture. For example, soil and water conservation practices can produce benefits alone, but they bring added benefits when commercial fertilizers are also used (30). Conservation practices can improve soil structure and increase soil organic matter. At the same time, they can slow water run-off and leaching below plant root zones and thus prevent fertilizers from being washed away. The mutually supportive effect of technologies—for example, using tied ridges and fertilizer—can be significant (table 5-2). The higher yields that result can offset the cost of introducing other technology (e.g., animal traction and irrigation) that allow the farmer to cultivate a larger area or extend the growing season.

The time frame for adoption of technological innovations will vary considerably across Africa based on agroecological factors and on the differing rates at which transitions to more intensive systems are possible, given socioeconomic conditions. Sequential changes to farming and herding technology are likely to be important. For example, resource-poor farmers and herders in semi-arid regions may be most able to adopt technologies in this sequence:

1. water-harvesting or run-off/erosion management systems,
2. increased use of organic fertilizer,
3. introduction of chemical fertilizers, then
4. introduction of improved cultivars (29b).

Each stage provides its own benefits and reduces the risk and increases the returns to the changes involved in the next stage. This type of sequencing may provide the most practical and cost-effective means of introducing packages of inputs. Sequencing also allows researchers and extension agents to focus their efforts more narrowly and farmers may be more likely to adopt new methods for the same reason. In sum, the sequential introduction of technology in support of low-resource agriculture may best be viewed as a natural evolution toward increased input use, but at a pace consistent with the highly variable agroecological and socioeconomic conditions in the region (29b).

Technology-Specific Potentials

The technologies discussed here have additional benefits, depending upon their specific characteristics. The following sections highlight that potential, summarizing information presented in more detail later in this report.

Table 5-2.—Economic Analysis of Farmer-Managed Trials of Sorghum With Fertilizer and Tied Ridges at Nedogo and Diapangou, Burkina Faso in 1983 and 1984

	Treatments[a]			
	C	TR	F	TR,F
		Nedogo: 1984, manual traction		
Grain yield, kg/ha[b]	157	416	431	652
Yield gain above control, kg/ha	—	259	274	495
Gain in net revenue, FCFA/ha[c]	—	23,828	13,275	33,607
Return/hr of additional labor, FCFA[d]	—	238	140	172
% farmers who would have lost cash	—	0	27	9
		Nedogo: 1983, manual traction		
Grain yield, kg/ha	430	484	547	851
Yield gain above control, kg/ha	—	54	117	421
Gain in net revenue, FCFA/ha	—	3,510	−2,285	17,475
Return/hr of additional labor, FCFA	—	35	—	90
% farmers who would have lost cash	—	0	66	0
		Diapangou: 1984, donkey traction		
Grain yield, kg/ha	498	688	849	1,133
Yield gain above control, kg/ha	—	190	351	635
Gain in net revenue, FCFA/ha	—	17,480	20,359	46,487
Return/hr of additional labor, FCFA	—	233	214	273
% Farmers who would have lost cash	—	0	21	0
		Diapangou: 1983, donkey traction		
Grain yield, kg/ha	481	522	837	871
Yield gain above control, kg/ha	—	71	356	390
Gain in net revenue, FCFA/ha	—	6,532	20,819	23,947
Return/hr of additional labor, FCFA	—	87	219	141
% farmers who would have lost cash	—	0	16	12

[a] C = Control (no tied ridges or fertilizer); TR = tied ridges constructed at second weeding; F = fertilizer: 100 kg/ha; 14-23-15 applied in band 10-15 cm from row at first weeding plus 50 kg/ha urea applied in pockets 10-15 cm from seed pockets at second weeding.

[b] The standard error and coefficient of variation (in percent) (in parentheses) starting with Nedogo, 1984 and continuing through to Diapangou, 1983 are 75 (43), 121 (29), 46 (18), and 43 (22), respectively.

[c] Net Revenue = yield gain x grain price (65 and 92 FCFA/kg in 1983 and 1984) minus fertilizer cost (62 and 78 FCFA/kg for 14-23-15, and 60 and 66 FCFA/kg for urea in 1983 and 1984—fertilizer prices are subsidized 40 to 50 percent). Includes interest rate charge for six months at rate of 15 percent. 1 U.S. dollar = 381 FCFA in 1983 and 436 FCFA in 1984.

[d] Net Revenue—additional labor of tied ridging and fertilizer application. Manual and donkey traction require 100 and 75 hours of additional labor/ha for tied ridging respectively. Fertilizer application requires 95 additional hours/ha.

SOURCE: Purdue University, International Programs in Agriculture, *Cereal Technology Development—West African Semi-Arid Tropics: A Farming Systems Perspective*, final project report for the U.S. Agency for International Development (West Lafayette, IN: 1987).

Potential Based on Improved Use of Natural Resources

Many experts believe that conserving and regenerating the natural resource base must become one of the highest priorities for the technical component of development assistance to Africa. Resource-poor farmers and herders depend on the land to supply life's basic requirements—food, fuel, fodder, and a safe and reliable water supply. Production can be increased and stabilized by more efficiently using existing resources. FAO has conducted some 55,000 technology demonstrations in Africa since 1961, covering improved management practices, improved crop varieties, and pest control. These trials show that improved management practices alone can raise yields 20 to 80 percent (tables 5-3 and 5-4). FAO estimates that full use of conservation measures, without changing crops or levels of inputs, could increase long-term land productivity for low-input agriculture by 33 percent (46).

Failing to undertake this work will have substantial costs. For example, soil erosion leads to loss of soil organic matter, which is necessary for plant growth because it improves soil structure, fertility and water availability. At least 25 million hectares in Africa's humid lowlands, subhumid tropical uplands, and tropical and subtropical highlands are subject to

Table 5-3.—Effect of Improved Practices, With and Without Fertilizers, on Crop Yields[a]

Country/zone	Crop	National average yield	Yield with improved practices[b]	Yield with improved practices and fertilizer
Burkina Faso (Sudano-Sahelian Africa)	Millet	430	520	1160
Cameroon (humid Central Africa)	Rice	840	1360	2500
Ethiopia (sub-humid and highland East Africa)	Maize	1100	2010	4100

[a] Yield in kilograms per hectare.

[b] These represent gains that can be achieved through improvements in management practices collectively. Table 5-4 shows the gains from the individual practices.

SOURCE: U.N. Food and Agriculture Organization, *Africa Agriculture: The Next 25 Years, Annex III: Raising Productivity* (Rome: 1986).

Table 5-4.—Gains From Improved Management Practices

Soil and water conservation	10 to 50%
Seed bed preparation	10 to 25%
Time of planting	10 to 50%
Plant population density	10 to 20%
Seed treatment	5 to 10%
Weeding	10 to 50%

SOURCE: Food and Agriculture Organization of the United Nations, *Africa Agriculture: The Next 25 Years, Annex III: Raising Productivity* (Rome: FAO, 1986).

extensive soil erosion, and even arid areas face serious risks during seasonal torrential rains (48). Long-term declines of agricultural productivity due to land degradation, mainly soil erosion, could be severe. FAO estimates that Africa could lose 16.5 percent of its rainfed cropland if degradation goes unchecked. Declines in land productivity could reach 25 percent due to losses in soil fertility, even accounting for some livestock production on degraded cropland (46).

Many technologies discussed in chapter 7 can reduce this problem. For example, terraces are a well-documented method that can virtually eliminate soil erosion caused by water run-off. Increases of 50 percent in maize production have been attributed to their use in the Kenyan Highlands (25). Windbreaks can effectively reduce wind erosion of soils, as well as protect young crop seedlings from wind abrasion. In one of the largest coordinated projects of its kind, the Majjia Valley Windbreak Project in Niger has resulted in average crop yield increases of some 20 percent on fields between windbreaks (9).

Potential Based on Improving Soil Fertility

Several technologies—minimum tillage, mulching, manuring, and agroforestry—improve soil fertility not only by reducing soil erosion, but by directly adding organic matter to soil. These types of technologies that improve soil fertility merit attention because they maximize the contribution of renewable resources and because of their low cost and accessibility. For instance, a substantial amount of nitrogen is already supplied by legumes and this contribution can be increased significantly by increasing their use in agroforestry, intercrops, and crop rotations. *Acacia albida*, an indigenous leguminous tree commonly intercropped with millet, sorghum, or groundnut, consistently increases the yield of the annual crops. In one documented case, millet and groundnut yields on infertile soils rose from 500 kg/ha to 900 kg/ha when grown with *Acacias* (12). Maize yields stabilized at about 2 tons/ha after 6 years of continuous alley cropping with leguminous trees, compared to no more than 0.5 ton/ha without alley cropping (22).

It is difficult to extrapolate legumes' potential contribution to production in Africa from these research results. Legumes probably cannot supply all the nitrogen necessary to grow enough food to feed Africa's current population, much less the additional people expected by the year 2000. But it is clear that legumes can make a significant, affordable contribution to Africa's forage and soil nitrogen needs. No more than 100 years ago, crop rotation with legumes was the principal means of restoring soil fertility in temperate zone agriculture. Now, it is an effective source of nitrogen used on numerous low-input farms that have developed in the United States during the last two decades. Africans have not had to rely on this deliberate use of legumes because shifting cultivation was an equally effective method of restoring soil fertility. Legumes were often a naturally occurring component of this process. The reintroduction of legumes into African agricultural systems could partially compensate for shortened fallows now.

Inorganic fertilizers will have an extremely important role in Africa's agricultural future, but they are likely first to supplement—not substitute for—organic fertilizers. As has been the case wherever they have been introduced, inorganic fertilizers will be used as they become available. Availability includes not only that they be affordable, but that their access be dependable and timely. Where adequate roads and markets exist for distribution and trained people for research and extension, as in Zimbabwe, commercial fertilizers are widely adopted and the benefits are impressive. Until the rest of Africa reaches this stage of development, however, the whole range of other fertility-enhancing technologies is likely to have high potential in many areas.

Potential Based on Improving Water Availability

Efforts to improve water use could first be directed at making more efficient use of freely supplied rainwater rather than relying on purchased inputs. For instance, recession farming (also called flood farming) is a high-productivity traditional practice used along major rivers of Africa. However, as dams become more common the traditional use of this technique is not possible unless special provisions are made. A proposal has been made to include a controlled, artificial flood as part of the plans for an irrigation project along the Senegal River. It remains to be seen whether such controlled flooding will allow farmers to reap the benefits of recession farming without interfering with dam operations.

Contour planting, water harvesting microcatchments, and tied ridges are all methods shown to be effective for improving rainfed agriculture under appropriate conditions. In most years these practices bring only slight yield increases. Their biggest advantages are realized during drought years, when improved fields are able to maintain yield levels while other fields experience crop failures (7,35). FAO estimates that low-cost technologies such as these can significantly improve at least 50 million hectares of arable land in subhumid and semi-arid Africa (48).

Unlike the technologies mentioned above, which in some ways are alternatives to irrigation, other practices exist that improve the efficiency of water use whether the source of the water is rain or irrigation. Technologies such as minimum tillage, mulching, and applying manure, increase infiltration rates as they improve soil quality, thereby increasing the amount of water that remains available for plant growth. Assistance to develop these practices is warranted even if they were evaluated simply for the contribution they can make to rainfed agriculture. But, in fact, they will be equally important in facilitating the transition to a more intensified agriculture that may include irrigation.

The technical benefits from small-scale irrigation, especially water pumping, are substantial and offer hope for overcoming the vagaries of an African climate notorious for erratic and often insufficient water supply. However, serious obstacles exist to wider implementation of irrigation technologies, and FAO, among others, estimates that increases in irrigation—large- or small-scale—will be minor for the foreseeable future (49). Adoption of small-scale irrigation technology will be a difficult and slow process.

Potential Based on Genetic Improvements

Crop and livestock breeding can be expected to make a larger contribution to agricultural development in the future than it has up to now. For example, new improved crop varieties exist that are able to yield more and do so on a more reliable basis because of their resistance to major pests and diseases and their greater tolerance to drought and other environmental stresses. Dramatic increases in milk production have been possible in some regions by crossing African cattle breeds with exotic dairy breeds.

Based on agricultural developments outside of Africa, and preliminary accomplishments within Africa, research to improve crops through genetics represents one of the best investments for supporting low-resource agriculture. This is less true for livestock breeding, however, where improved management (e.g., attention to nutrition, disease, and climatic stress) is a prerequisite to gains through genetic improvement. Plant breeding, however, may increase animal productivity given the increasing use of crop residues as animal fodder.

The yield increases obtained in plant and animal breeding research can be dramatic, but they seldom have been realized by farmers and herders when conditions are less favorable. The gap between results achieved on-station and on-farm will be reduced as decreased emphasis is placed on breeding materials suited for actual conditions.

Photo credit: J. Van Acker/U.N. Food and Agriculture Organization

Considerable potential exists to enhance low-resource agriculture by making genetic improvements in crops and livestock and by better integrating animal and cropping systems.

Potential Based on Improved Integration of Animal and Cropping Systems

The integration of animals into cropping systems is expected to increase as techniques such as fodder banks and alley cropping enable farmers to maintain animals more readily. Livestock make numerous contributions to food security needs, including: providing milk and meat, and acting as food reserves; providing a source of income, savings for emergencies, and export earnings; and providing animal traction. Small ruminants (e.g., goats and sheep), in particular, have been neglected by development assistance but could become more important in the future.

Animal traction allows more land to be cultivated and it becomes more cost-effective when crops can generate cash, which can then be used to repay loans for purchasing and maintaining the animals as well as purchasing other inputs. Present rates of return can be doubled and tripled as animal power becomes available for weeding and other farming activities, rather than just for plowing. For example, weeding, which is a major labor bottleneck for most farmers, can be performed six times faster with animal traction. Better adapted implements will assist in this process, but other constraints are farmer unfamiliarity and the initial expense of purchasing animals. Extension will be instrumental to enable farmers to take advantage of animal traction for a variety of farming activities (20).

Aquaculture can contribute to food security by supplying high protein food and by generating income to purchase food. Farm by-products, such as animal manure and crop residues, can be used to stimulate fish production from aquaculture. Enriched pond water can be used to irrigate home gardens, completing the recycling process.

Potential for Reducing Food Losses

Integrated Pest Management (IPM), using the best mix of available pest control methods, can significantly reduce field losses in a cost-effective, sustainable, and safe manner. Human and environmental health is improved because IPM emphasizes only judicious application of pesticides in conjunction with other pest control practices, rather than relying on pesticides alone. The objective of IPM is to reduce pests to an acceptable level rather than trying to erradicate them altogether.

Post-harvest losses also can be reduced, using technologies adapted to the socioeconomic and environmental features of the farming system. Perhaps more important than the food saved are the labor savings. Improved technologies exist that can reduce labor needs and make operations more efficient. Women, who have primary responsibility for post-harvest activities, are the main beneficiaries, with subsequent benefits accruing to the whole household.

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Chapter 6

The Role of Foreign Assistance in a Resource-Enhancing Approach

CONTENTS

Page
Highlights 123
Congress and a Resource-Enhancing Approach 124
  Congressional Direction and a Resource-Enhancing Approach 124
  Congressional Funding and a Resource-Enhancing Approach 125
  Congressional Oversight and a Resource-Enhancing Approach 132
Three Categories of Development Assistance for a Resource-Enhancing Approach 134
  Development Assistance at the Local Level 134
  Development Assistance in Support of Formal Agricultural Institutions 140
  Development Assistance To Support National Level Policy Reform 146
AID and a Resource-Enhancing Approach 148
  AID's Strategy 148
  AID's Operations 150
Chapter 6 References 153

Boxes

Box *Page*
6-1. The Language of Foreign Aid 128
6-2. Constraints on AID's Operations: Lessons From the Sahel 151

Tables

Table *Page*
6-1. U.S. Bilateral Economic and Military Assistance to Sub-Saharan Africa, 1980-87 127
6-2. AID Economic Support Funds (ESF) as a Percent of the Africa Bureau's Agriculture Portfolio, 1979-87 129
6-3. U.S. Support of Multilateral Development Institutions, 1980-88 130
6-4. U.S. Contributions to Multilateral Development Banks Funding African Development, 1978-87 131
6-5. The Peace Corps in Africa, 1980-87 136
6-6. AID Funding for Agricultural Education and Training in the Africa Bureau's Agriculture Portfolio, 1979-87 141
6-7. AID Funding for Agricultural Research and Research Capacity in the Africa Bureau's Agriculture Portfolio, 1979-87 143
6-8. AID Funding for Policy Reform and Economic Stabilization in the Africa Bureau's Agricultural Portfolio, 1979-87 147
6-9. World Bank Policy Reform Lending to Sub-Saharan Africa, 1984-87 147
6-10. AID Funding for Agriculture in the Africa Bureau's Budget, 1979-87 149

Chapter 6

The Role of Foreign Assistance in a Resource-Enhancing Approach

HIGHLIGHTS

- Congressional direction regarding foreign assistance reflects the needs of low-resource agriculturalists but lacks clear-cut priorities and is often subject to contradictory nondevelopment interests.
- Stable long-term funding of bilateral development assistance and multilateral programs are required for effective implementation of a resource-enhancing approach.
- The importance of improved, but less burdensome, congressional oversight to ensure the effectiveness of U.S.-supported foreign assistance to Africa has increased due to changes in fiscal year 1988 appropriation bills but the success of oversight also depends upon improved AID/congressional relations.
- A resource-enhancing approach would include support for local-level groups and agricultural institutions, and national level policy formulation and implementation.
  —Though major donors have not had great success using resource-enhancing approaches at the local level, private voluntary organizations and the Peace Corps have had better results, and local African organizations and the rural non-farm private sector provide opportunities for future efforts.
  —AID and the World Bank are among the major donors providing training and other support for African agricultural institutions, though with mixed results. A major problem has been their lack of attention to developing effective links between these institutions and low-resource farmers, herders, and fishers. The International Agricultural Research Centers have had similar problems.
  —AID and the World Bank have made policy reform a major focus of their African programs. Insufficient farm-level analysis and evidence that current policy reform programs may not help and indeed may harm low-resource agriculturalists point to a critical need to evaluate current policy reform programs.
- As the largest agency for U.S. development assistance, AID's capabilities to implement a resource-enhancing approach will have a major effect on U.S. efforts.
  —AID's Africa strategies, while supportive of low-resource agriculturalists in theory, have been less than effective in practice. They also reflect a trend away from direct support for farmers, fishers, and herders in favor of a focus on policy reform and macro-economic growth.
  —Operational difficulties continue to hamper AID's implementation of its strategies and undermine benefits of recent operational changes such as those towards decentralized decisionmaking; longer term, more flexible programming; and improved information and evaluation systems need to be reinforced.

CONGRESS AND A RESOURCE-ENHANCING APPROACH

Congress stands at an important juncture concerning development assistance to Africa (62). The need to decide on a future direction for U.S. assistance stems from the convergence of several factors.

First among these is frustration in Congress over the limited impact past assistance has had. Recurring famine and general economic decline, despite substantial U.S. assistance, have led to considerable doubts about the merits of past programs and to calls for different development approaches.

Secondly, significant modifications in foreign assistance programs have been made since the last major legislative overhaul in 1973 introduced the human needs approach of the so-called New Directions legislation. Further changes have been proposed. The Administration has advocated a macroeconomic approach focusing heavily on policy reform in recipient countries. This change is seen by some as a sharp departure from the New Directions legislation. Others see it as complementary to the objective of providing basic human needs, but this depends on how it is implemented.

A third factor is resistance on the part of many in Congress to increasing foreign assistance at a time of domestic budget tightening. While appropriations for fiscal year 1988 show increased congressional and Administration attention to Africa's development needs, concerns remain over maintaining this commitment for the long term. Contributing to these concerns are the lack of deep political support and a constituency for development assistance as compared with other forms of foreign assistance, for example, military or politically motivated aid (30).

Support for social and economic development for resource-poor agriculturalists, as Congress responds to the challenges of this juncture, would require use of its powers of authorization, appropriation, and oversight:

- *Authorization:* Congress could provide clearer direction on the use of development assistance, ensure flexibility to account for Africa's diversity and reduce the impacts of contradictory nondevelopmental objectives.
- *Appropriation:* Congress could provide long-term, stable funding for development assistance at levels balanced with other foreign policy and security issues as well as domestic priorities.
- *Oversight:* Congress could improve the quality of oversight while reducing its disruptive effects on development agencies.

Congressional Direction and a Resource-Enhancing Approach

Most elements necessary in a development assistance approach designed to enhance low-resource agriculture are already included in existing foreign assistance legislation.[1] This legislation emphasizes:

- development;
- long-term strategies;
- focus on the poor majority;
- equitable, self-sustaining economic growth;
- agricultural development and the role of the small farmer;
- leadership and participation by the developing nation and the indigenous people; and
- the role of women in development.

Although these elements are included in legislation, their effect could be enhanced if Congress gave clearer direction, set explicit priorities, and sought to reduce the influence of other political and economic interests.

Setting Clear Priorities

The proliferation of cumulative congressional mandates concerning development assistance has hindered the work of executive branch agencies, particularly AID, by providing an overabundance of priorities without clearly ranking them. This has reduced long-term consistency, and forced AID to use resources on mandates that may not be relevant in specific cases or whose goals may not be clear (63,64). In addition, Congress has not fully evaluated current Administration priorities (e.g., policy reform and private sector development) nor integrated them into existing legislative strategies. This lack of clarity has reduced Congress' ability to maintain and modify the direction of U.S. assistance. Clarity in direction and prioritization do not, however, mean rigidity. Africa's diversity and its rapid evolution require flexible direction and priorities from country to country and over time. Rigidity in direction can lead donors to abandon successful forms of support or to use inappropriate methods, as they did during the application of the New Directions legislation of 1973 (30).

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[1] The congressional direction steering foreign assistance discussed here appears in the development assistance sections of the Foreign Assistance Act of 1961, as amended, and the Agricultural Trade Development and Assistance Act of 1954, as amended.

Making food security an overarching goal of development assistance offers one means to integrate existing congressional directives and provide a framework for setting priorities. Having food security as a goal could enable AID and other U.S.-supported development agencies to adapt their work to local conditions—whether it be increasing food or export crop production, stabilizing or diversifying agricultural production, or working with non-farm activities. Second, food security could be used to develop indicators of progress in reaching Congress' goal of equitable, self-sustaining economic growth. If economic growth occurs but food security among the poor does not increase correspondingly then growth is not equitable.

Reducing the Negative Impacts of Non-developmental Interests

Many political and economic pressures cause Congress and the Administration to use development assistance in ways that may be less than optimal for developmental goals such as ensuring food security (63,64). Foreign assistance to Africa is influenced by objectives including:

- ensuring pro-U.S. political and strategic relations bilaterally and in international forums;
- ensuring access to strategic commodities;
- promoting U.S. exports including restricting assistance that may potentially cause competition for U.S. exports (e.g., restricting support for research on palm oil); and
- building U.S. domestic political support by directing development contracts to constituents.

Development assistance's weak political constituency and AID's dependent status vis-à-vis the State Department, have allowed others (e.g., the Departments of State, and Agriculture, and Congress) to apply pressure successfully for the use of development assistance for non-developmental objectives. In some cases, non-developmental interests have taken precedence over developmental goals and even, some have argued, undermined overall U.S. foreign policy interests.

Development and non-development goals, however, can be complementary, especially in the long term. For instance, increased African food security and agricultural development can contribute to political and economic stability and, in the long term, can offer the United States increased economic opportunities for trade. This convergence, the significant U.S. humanitarian interest in the region, and the desire to avoid any future need for large-scale famine relief, justify Congress' stated priority on development as the primary U.S. goal in Africa. These factors provide a rationale for resisting the pressures of conflicting interests and for reducing certain program and procurement restrictions.

Congressional Funding and a Resource-Enhancing Approach

U.S. funding for agricultural development may go directly to African nations (as bilateral aid) or pass via multinational organizations (as multilateral aid). The implementation of a successful resource-enhancing approach would require long-term, stable funding to support agricultural development in both cases. As will be discussed, agricultural research, training, building agricultural institutions, and supporting local organizations require long-term commitments and can be damaged by fluctuating support. The likelihood of long-term stable support is problematic, however, given that:

- current mechanisms constrain Congress from ensuring stable levels of funding in support of African agricultural development,
- ongoing pressures to reduce the Federal budget are likely to continue, and
- current implicit priorities favor bilateral security assistance over development assistance.

Bilateral Assistance

Economic assistance (versus military aid) comprises the majority of U.S. bilateral aid to Africa (table 6-1) and AID provides the majority of this economic assistance. AID divides congressional appropriations for agricultural assistance primarily into three funding sources: Development Assistance accounts (DA), Economic Support Funds (ESF), and food aid (box 6-1). Of the three sources, DA seems best suited for providing stable levels of funding necessary for a long-term approach to support resource-poor agriculturalists. This is because congressional direction guiding DA is the most compatible with the objectives of assisting low-resource agriculturalists, and because DA funding is the most likely to remain stable over time. Congress has already shown interest in stabilizing and protecting DA levels for Africa. During the budget reductions of fiscal year 1987, Congress mandated that Africa receive the same percentage of DA as in the previous year (Public Law 99-500). Congress created a separate DA fund for Africa in fiscal year 1988 with an increased funding level (Public Law 100-202). Constraints on the dependability and appropriateness of the other two sources (ESF and food aid) include:

- ESF is allocated primarily for political and security purposes often leading to rapid and substantial changes in annual country allocations.
- Congress normally has earmarked the majority of ESF for countries outside Sub-Saharan Africa. To protect these earmarks in times of budget reduction, Africa has received lower percentages of ESF.
- Food-aid levels can swing substantially due to changing recipient needs and the availability of U.S. grain.
- Significant questions remain concerning the effectiveness and possible negative impacts of using non-emergency food aid to support development.

Military assistance, though not intended to have a developmental impact, may have negative impacts, nonetheless, by absorbing funds that could have gone to development and by fostering local economic distortions in the recipient nations. Military assistance traditionally has been a relatively small component of assistance to Africa, comprising no more than nine percent of total U.S. assistance over the last 40 years (62). However, military assistance doubled between 1980 and 1985 and correspondingly increased from 9.4 percent of the bilateral assistance budget to 13.4 percent. Military assistance is estimated to have declined to 6 percent in 1987. AID has cautioned that "our military aid programs must be undertaken cautiously and with due regard for their possible negative impact on domestic resource allocation as well as on foreign exchange and debt servicing" (51).

Development Assistance (DA) to Africa has fluctuated since 1980 and did not keep pace with overall increases between 1980-1985 in total bilateral assistance worldwide and to Africa (table 6-1). U.S. foreign assistance worldwide increased dramatically over that period primarily due to increases in ESF ($4 billion increase) and military assistance ($5.4 billion increase). Africa received a relatively small portion of this increase, mainly through ESF, except for 1985 when high levels of food aid were provided. When measured in constant dollars, DA declined for Africa between 1980 and 1987. Fiscal year 1988 congressional appropriations of $500 million in DA for Africa plus $50 million for projects of the Southern African Develop-

Table 6-1.—U.S. Bilateral[a] Economic and Military Assistance to Sub-Saharan Africa, 1980-87

	Total Military plus Economic Assistance	Military Assistance (MA)		Economic Assistance (EA)	Components of Economic Assistance									
					Development Assistance		Economic Support Fund		Public Law 480		Peace Corps		African Development Foundation[b]	
Year	Obligation (millions $)	Obligation (millions $)	Percent of MA+EA	Obligation (millions $)	Obligations (millions $)	Percent of EA	Obligations (millions $)	Percent of EA	Obligations (millions $)	Percent of EA	Obligations (millions $)	Percent of EA	Obligations (millions $)	Percent of EA
1980 ...	**824.1**	77.3	9.4	746.8	282.2	38.0	132.7	18.0	293.3	39.3	38.6	5.2	—	—
1981 ...	**908.9**	84.7	9.3	824.2	300.3	36.4	163.0	19.8	322.1	39.1	38.8	4.7	—	—
1982 ...	**1,064.1**	191.3	18.0	872.8	328.8	37.7	294.8	33.8	208.6	23.9	40.6	4.7	—	—
1983 ...	**1,015.6**	134.0	13.2	881.6	315.3	35.8	286.1	32.5	239.3	27.1	40.9	4.6	—	—
1984 ...	**1,143.4**	153.3	13.4	990.1	340.4	34.4	333.1	33.6	271.3	27.4	43.6	4.4	1.7	0.2
1985 ...	**1,679.0**	168.0	10.0	1,510.9	352.2	23.3	417.8	27.7	689.4	45.6	47.0	3.1	4.5	0.2
1986 ...	**1,126.1**	103.2	9.2	1,024.0	378.9	37.0	245.2	23.9	347.6	33.9	46.3	4.5	6.0	0.6
1987 ...	**836.4**	52.3	6.3	784.0	328.1	41.8	162.8	20.8	237.7	30.3	48.8	6.2	6.6	0.8

[a] Bilateral assistance does not include contributions to multilateral institutions nor obligations of central AID bureaus or the State Department. Figures have been rounded.

[b] The African Development Foundation became operational in 1984 to provide relatively small amounts of assistance to local African groups.

NOTE: For fiscal year 1988, $550 million in DA was appropriated for Africa along with $90 million earmarked for ESF.

SOURCES: U.S. Agency for International Development, *Congressional Presentation*, fiscal years 1981-87.

Box 6-1.—The Language of Foreign Aid

Agricultural assistance: a generic term for any U.S. economic assistance funding used for supporting agricultural development.

Agricultural Portfolio: activities in support of agricultural development funded through AID's Africa Bureau using DA and ESF funds. It does not include activities funded by Public Law 480 nor by AID's other bureaus.

Bilateral assistance: assistance provided by the United States directly to African nations. For this report, bilateral assistance includes ESF, Public Law 480, DA provided by the Africa Bureau of AID, Peace Corp funding, and military aid.

Economic assistance: used to refer to all non-military assistance.

Development Assistance (DA): DA suffers from a multitude of definitions. For the purpose of this report, DA is the set of bilateral U.S. funds:

1. whose principle use is the support of development,
2. that are administered by AID,
3. whose funding levels are directly set by Congress, and
4. whose development goals are set by Congress in Chapter 1, Part I of the Foreign Assistance Act of 1961, as amended.

These funds include, the Private Enterprise Revolving Fund, the Science and Technology Fund, the Sahel Development Program, and six Functional Development Accounts:

1. Agriculture, Rural Development, and Nutrition;
2. Population Planning;
3. Health;
4. Child Survival;
5. Education and Human Resources Development; and
6. Private Sector, Environment, and Energy.

Congress created a 1-year separate African DA account of $500 million for fiscal year 1988 in addition to $50 million for projects supported by the Southern Africa Development Coordination Conference. This fund will replace the six Functional accounts and the Sahel Development Program as the primary source for African DA.

Economic Support Fund (ESF): Through ESF, AID supplies economic assistance to countries where the United States has political, economic, or security interests. ESF can be provided in cash transfers, U.S. commodities, or project aid (similar to DA-funded projects). Cash and commodities are quick ways to supply budgetary support. ESF is not governed by the same congressional mandates as DA and is authorized under Part II, chapter 4 of the Foreign Assistance Act of 1961, as amended. Congress sets the overall funding level for ESF and commonly earmarks a majority of it for specific countries (i.e., Congress mandates certain amounts of ESF for certain countries with the division of the remainder left to the Administration's discretion).

Food Aid: Excess U.S. agricultural commodities may be provided as aid on a concessionary loan or grant basis primarily under three laws:

1. The Agricultural Trade Development and Assistance Act of 1954 (Public Law 480)
   a. Title I of Public Law 480: provides long-term credits (authorized on an annual basis) at low-interest to buy U.S. farm products. Local currencies generated by the in-country sale of the food can be used for development activities.
   b. Title II of Public Law 480: provides food aid grants during famine or other emergencies and supplements regular feeding programs.
   c. Title III of Public Law 480: known as Food for Development, Title III uses Title I funds but offers multiyear programs and loan forgiveness in return for undertaking specific development activities.
2. Section 416 of the Agricultural Act of 1949 offers a second source of grant food aid to support Title II-like programs.
3. Food for Progress, which is authorized under the Food Security Act of 1985, provides additional Title I and Section 416 resources in return for agricultural policy reforms.

ment Coordination Committee halted the actual and relative decreases in DA. Questions remain, however, as to whether this reversal will be maintained in the longer term.

Assistance provided for agricultural development in Africa also fluctuated between 1980 and 1987, first rising then falling. Obligations in the Africa Bureau's agricultural portfolio rose from $265 million in 1980 to a peak of $400 million in 1985 and then declined to an estimated $317 million for 1987. Changes in ESF funding have been responsible for much of the change in AID's agricultural assistance (table 6-2). The use of ESF funds as a significant component of agricultural assistance poses two possible problems that could constrain agricultural development. First, as seen in table 6-1, year-to-year fluctuations in ESF levels for Africa are substantial, making it difficult to build a development program based on long-term ESF financial commitments. Second, ESF is used primarily for policy reform and budget support (58). Reliance on ESF as a major source of agricultural assistance could thus bias the overall U.S. strategy away from local-level agricultural development. The risk of such a bias has declined since 1985 due to reductions in ESF levels for Africa.

Current bilateral funding mechanisms have made it difficult for Congress to direct funds towards agricultural development in Africa. AID's agricultural funding is derived from several separate congressionally authorized and appropriated sources, primarily ESF, Public Law 480, and two DA accounts (Agriculture, Rural Development and Nutrition, and the Sahel Development Program). All but the latter fund agricultural assistance worldwide and are not restricted to Africa. The Sahel Development Program, in addition to agriculture, includes all types of development programs for nine West African countries.[2]

Neither Congress nor AID has expressed interest in creating additional earmarked African agricultural funds. The Administration and Congress in 1987 proposed a single fund for African DA to help maintain stable levels of DA for Africa, provide AID with the opportunity for longer term planning, and allow AID increased programming flexibility. Congress funded such an African DA fund with a one-year appropriation of $500 million in the Continuing Resolution for appropriations in fiscal year 1988 (Public Law 100-202). While it is too early to determine the fund's impact, its success will in part depend on whether Congress maintains its commitment to the fund, on how AID uses the increased flexibility provided, and on whether AID and Congress ensure that the appropriations to the fund are not diverted to other programs.

Like the earlier DA accounts, the new fund does not provide Congress with the means to set levels directly for agricultural assistance. The fund does contain target levels of spending for health, voluntary family planning, and maintaining the renewable natural resource base, but neither earmarks nor targets are included for agriculture. The 1987 authorization bill for the fund contained language directing support for agricultural development, but it did

Table 6-2.—AID Economic Support Funds (ESF) as a Percent of the Africa Bureau's Agriculture Portfolio[a], 1979-87

	1979	1980	1981	1982	1983	1984	1985	1986	1987 (est.)
Obligations	12.5	24.6	20.3	20.2	28.9	34.5	42.4	28.9	29.0
Expenditures	6.6	24.2	26.5	11.7	27.9	27.5	32.9	34.5	32.8

[a] The agriculture portfolio includes AID's Africa Bureau funding for DA and ESF. It does not include Public Law 480 funding nor funds used by other AID Bureaus.

SOURCE: U.S. Agency for International Development, Africa Bureau, *Agriculture and Rural Development: Functional Review FY 1978-1987*, July 1986, updated 1987.

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[2] The issue of the amount of bilateral funds being spent on African agriculture is further clouded because of involvement of more than one AID Bureau. While a majority of funding for Africa goes through the Africa Bureau, other bureaus such as Science & Technology, Policy and Program Coordination, Private Enterprise, and Food for Peace and Voluntary Assistance, have programs concerning agriculture development in Africa. No single AID data system provides a breakdown of all AID's agricultural funding to Africa for each of these bureaus (or for AID as a whole).

not pass. The Conference Report (Report 100-498) concerning fiscal year 1988 foreign assistance appropriations includes only vague direction for agricultural uses of the fund. Congress' difficulty in directing funds specifically to African agricultural development and the resulting increased flexibility for AID to determine the level and direction of its program indicate an increased importance for effective congressional oversight regarding AID's support for resource-enhancing approaches to agricultural development.

Multilateral Assistance

U.S. multilateral development assistance makes up about 11 percent of the total U.S. foreign aid budget for fiscal year 1988 and is provided to several types of organizations (45). The multilateral development banks (MDBs) receive the majority of U.S. assistance and two of them, the World Bank and the African Development Bank, support agricultural development in Africa. The World Bank is the primary lender. A second set of organizations has been lumped under the funding category International Organizations and Programs which, like the MDBs, have their individual funding levels set by Congress. The United Nations Development Program (UNDP), the International Fund for Agricultural Development (IFAD), and the United Nations Children's Fund (UNICEF), each with African agriculture-related programs, receive the majority of the funding under this category (at least 75 percent since 1981). A third category is organizations in which the United States participates and which assess the United States a membership fee, usually a percentage of the organization's budget (e.g., the U.N. Food and Agriculture Organization, which assesses the United States a fee equal to 25 percent of its annual budget). Other international organizations may receive funds directly from U.S. agencies. For example, the 13 international agricultural research centers of the Consultative Group on International Agriculture Research (CGIAR) system receive their U.S. contributions through AID.

Funding to the first two groups, international organizations and multilateral development banks, has followed the general trend in bilateral assistance by increasing between 1980 and 1985 and then declining through 1987 (table 6-3). Although the following discussion focuses on multilateral development banks, the other organizations can also play important roles in the enhancement of low-resource agriculture. For example, a 1985 AID evaluation found that "IFAD is making a significant contribution to improving the economic conditions of the rural poor in developing countries" partly through the use of technologies adapted specifically for small, low-income farmers (52).

The World Bank and the African Development Bank provide two types of loans. The

Table 6-3.—U.S. Support of Multilateral Development Institutions, 1980-88

	Obligations (millions $)								
Organization	1980	1981	1982	1983	1984	1985	1986	1987	1988[a] (est.)
International Organizations and Programs[b]	208[c]	210	215	270	315	362	266	237	245
Multilateral Development Banks	1,478	986	1,262	1,487	1,324	1,548	1,143	1,207	1,206
Total	1,686	1,196	1,476	1,757	1,639	1,910	1,408	1,444	1,450

[a] Congressional appropriation

[b] Includes support for certain development, humanitarian, and scientific programs of the United Nations and the Organization of American States funded by voluntary government contributions, according to the AID *Congressional Presentations*, fiscal years 1980 through 1988.

[c] 1980 data do not include $52 million for the U.N. Relief and Works Agency in order to provide consistent data. Funding for the U.N. Relief and Works Agency was switched from the International Program funding to the U.S. Department of State's Migration and Refugee Account in the years following.

SOURCES: U.S. Agency for International Development, *Congressional Presentations*, for fiscal years 1981 through 1988 (Washington, DC: AID).
U.S. Department of State, *United States Contributions to International Organizations: Report to the Congress for Fiscal Year 1985* (Washington, DC: U.S. Department of State, 1986).
Sanford, Jonathan, "Multilateral Development Banks: Issues for the 100th Congress," IB87318 (Washington, DC: Congressional Research Service, Library of Congress, Jan. 12, 1988).

World Bank's International Bank for Reconstruction and Development (IBRD) and the African Development Bank (AfDB) borrow from world capital markets and provide loans to developing countries at near-market interest rates. The World Bank's International Development Association (IDA) and the African Development Bank's African Development Fund (AfDF) provide long-term, below market interest loans to the poorest developing countries (countries having per-capita GNP below $791 in 1984 dollars). IDA has provided the majority of World Bank lending for African agricultural development and is especially important in the poorest countries but, IBRD has also provided a significant portion of agricultural funding, especially for West Africa (75).

U.S. funding of the World Bank has been erratic over the past decade (table 6-4). For IDA 8 (the 3-year replenishment beginning in 1988), the United States has pledged a total of $2.875 billion or approximately $960 million per year, subject to congressional appropriation. In the past, Congress has stretched some 3-year commitments to 4 years and thereby reduced the United States' contribution. For fiscal year 1988, Congress has appropriated $915 million for IDA. Forty-five percent of all donors' contributions to IDA 8 are earmarked for Africa and approximately 60 percent are intended for policy reform.

U.S. contributions to AfDF have risen more predictably from $10 million in 1978 to $90 million in 1987. Contributions to AfDF have not been reduced by the current budget reductions in part because AfDF receives a comparatively small contribution and because its work is readily identifiable with African development.

U.S. contributions to IBRD and AfDB are more difficult to assess because both banks borrow money on capital markets for their lending. Donors contribute to each in two ways: through direct capital contributions and via money held against potential defaults (callable capital). Part of the U.S. contribution (7 percent for the IBRD in 1987) is used to increase the financial stability of the bank, increase its borrowing ability, and act as a source of funds if recipients default (44).

Table 6-4.—U.S. Contributions to Multilateral Development Banks Funding African Development, 1978-87

Year	Congressional appropriations (millions $)[a]					
	The World Bank				AfDB[b]	AfDF[b]
	IBRD[c]	IDA[d]	Special Facility for Sub-Saharan Africa[e]	IFC[f]		
1978	38.0	800.0	—	38.0	—	10.0
1979	16.3	1,258.0	—	40.1	—	25.0
1980	16.3	1,072.0	—	19.0	—	25.0
1981	32.8	520.0	—	—	18.0	41.7
1982	146.9	700.0	—	14.5	—	58.3
1983	126.0	945.0	—	—	—	50.0
1984	79.7	945.0	—	—	18.0	50.0
1985	139.7	900.0	—	—	18.0	50.0
1986	105.0	669.9	71.8	27.8	15.5	60.0
1987	55.8	830.1	64.8	7.2	20.5	90.4
1988[g]	40.2	915.0	—	20.3	9.0	75.0

[a] Data for IBRD and AfDB reflect paid in capital and do not include callable capital.

[b] AfDB and AfDF: African Development Bank and African Development Fund. These are African equivalents to the IBRD and IDA, respectively, and provide near-market rate loans and concessional rate loans to the poorest countries in Africa.

[c] IBRD: International Bank for Reconstruction and Development. IBRD borrows from world capital markets and makes loans at near-commercial interest rates for productive purposes mainly to middle income countries.

[d] IDA: International Development Asociation. IDA makes concessional (no interest) loans to the poorest countries for productive purposes. Funding is obtained from developed countries and IBRD earnings.

[e] Special Facility for Sub-Saharan Africa. A special 3-year fund set up in 1985 to make loans in support of policy reform work in IDA-eligible African countries. Funding is obtained and supplied along IDA lines.

[f] IFC: International Finance Corporation. The IFC makes loans and equity investments in local privately owned firms in developing countries.

[g] Data for 1988 do not include a $44.4 million, first-time contribution to the new Multilateral Investment Guarantee Agency of the World Bank whose purpose is to provide noncommercial risk insurance for private investment in developing countries.

SOURCES: Jonathan Sanford, "Multilateral Development Banks: Legislation Affecting U.S. Participation" (Washington, DC: Congressional Research Service, June 29, 1987).
Jonathan Sanford, "Multilateral Development Banks: Issues for the 100th Congress," IB8731B (Washington, DC: Congressional Research Service, Jan. 12, 1988).

Legislated congressional direction to multilateral banks working in Africa has recently stressed the need to ensure environmental sustainability of funded projects, increase attention to the poor and to women, and increase participation of indigenous organizations having grassroots connections to the poor (H.R. 3750 which was passed as part of the Continuing Resolution for fiscal year 1988). Congress has not given agricultural development the same attention. In fact, legislation reauthorizing U.S. participation in the multilateral development banks is concerned more with possible agricultural competition with the United States than the type of agricultural development the banks are supporting (H.R. 3750).

Congress cannot set agricultural funding levels because these organizations are independent agencies. It can, however, direct the U.S. representative to each bank to lobby for making agricultural development even more of a priority. Twenty-seven percent of the World Bank's assistance to Africa went to agriculture and rural development between 1981 and 1985, and in 1985 the AfDF allocated 38 percent of its funding to agriculture. Because appropriating money directly for development of African agriculture is not a possibility, congressional oversight, backed by appropriations activity, will remain an important way to influence these organizations.

Congressional Oversight and a Resource-Enhancing Approach

More effective congressional oversight is crucial to the implementation of an approach to enhance ~~low-resource~~ agriculture via bilateral and multilateral programs. Congress has legislated many elements of such an approach and appropriated funding for agricultural development. But concerns remain regarding AID and the World Bank's apparent difficulties in carrying out programs which support resource-poor farmers, herders, and fishers.

Coordinating and Improving Oversight

In-depth and long-term oversight is hampered by the time constraints and lack of relevant knowledge facing Members of Congress and their staff. Individual members and small staffs have little time to respond to complex long-term development issues when these are only one part of their wide and demanding responsibilities. Responding to inadequately prepared oversight activities may divert donor agency resources and can have adverse impacts on development programs. These problems are aggravated and others are created by the many congressional actors involved in development assistance oversight and the lack of coordination among them. In addition to individual member queries, seven committees (and additional subcommittees) have direct jurisdiction over U.S. agricultural assistance, and still others have oversight authority.

This duplication of effort also at times results in contradictory directions from Congress. It could be reduced by increasing formal and informal cooperation among those currently involved in oversight. Such cooperation has the potential for increasing the quality of oversight without increasing the energy and money spent on it, helping maintain consistency in U.S. programs as individuals and issues change, and reducing the wasted resources involved in AID and others having to respond to similar requests from different sources.

To improve the quality of information available, interested committees could improve their expertise in development by establishing groups of development experts to advise them on AID and other donors' work. Congress could increase its consultation with persons having long-term AID experience in the field and in Washington, DC. This could be accomplished by increasing informal contacts, increasing the provision of congressional fellows from AID, and by having congressional staff attend meetings of AID mission directors and development officers in the field.

Oversight could also be improved by increasing the availability of information concerning how and where assistance is used. The Congressional Research Service's computerized foreign assistance budget could be expanded to provide a better view of where money is being spent. AID's own ability to provide information on its agricultural work in Africa is severely constrained by the lack of a central disaggregated database.

Reducing the Burden of Oversight

Congress has placed a series of reporting and procurement requirements and restrictions on AID's work. According to AID, these have used up large amounts of resources while reducing their ability to respond to the diverse conditions in Africa. Though a detailed analysis of AID's operations was not included in this assessment, other OTA work indicates cause for concern (64). AID has testified that at least 200 person-years are necessary to respond to congressional reporting requirements and information requests regarding AID's work worldwide (67). These requirements and restrictions include:

- notification of reprogramming of funds;
- responses to information requests by multiple committees and individual members;
- mandated reports;
- procurement requirements (e.g., buying only U.S. products unless a time-consuming waiver can be obtained);
- restrictions on aid to individual countries;
- restrictions on aid aimed at increasing production of specific commodities;
- informal earmarking of funds; and
- formal earmarking of funds.

Direction on the use of funds and effective congressional oversight are crucial responsibilities of the U.S. legislative branch of government. But opportunities clearly exist for Congress to reduce the unnecessary burden of its demands and restrictions on AID. Previously discussed steps to improve the quality and depth of oversight such as clarifying priorities, coordinating oversight, and reducing pressures to use aid for non-developmental purposes would be likely to also decrease oversight's burden. Other congressional actions that could increase AID's effectiveness include reducing the need to buy only U.S. equipment and commodities. These restrictions often result in the acquisition of goods which are more expensive and often inappropriate to African conditions. Alternatively, they require substantial paperwork to qualify for an exemption. For fiscal year 1988 Congress addressed this concern by exempting the new African DA fund from the restriction to buy only U.S. products.

Another way to reduce AID's reporting burden would be to modify the requirement that AID notify Congress of funding changes. AID has argued that since only about 3 percent of such notifications are of interest to congressional committees, notification of low-level changes in funding, perhaps of 10 percent or less of a project's budget, could be eliminated (67). Congress did reduce reprogramming notifications for DA in the fiscal year 1988 appropriations. Evaluating the impacts of this reduction and the "buy-American" exemption for Africa will be important for considering their extension and possible expansion.

The issue of congressional earmarking for the use of funds is more controversial. Disposing of formal earmarks and reducing pressures for informal earmarks would increase AID's flexibility, but it is uncertain that AID would use that flexibility to carry out Congress' intentions. AID's failure to address the needs of resource-poor agriculturalists, despite congressional direction to do so, raises concerns about the effects of providing AID with additional flexibility. Earmarks are a visible means (though not necessarily always an effective one) for Congress to ensure that assistance funds are spent in accordance with congressional direction. Congress has done away with the majority of earmarks for African DA for fiscal year 1988. While three spending targets (each one 10 percent of the fund) are set for health, voluntary family planning, and renewable resources, the fund provides AID with increased flexibility to program remaining money. A successful outcome for this greater flexibility will depend on more responsiveness on AID's part, and on more effective, less burdensome oversight. Continuing and increased flexibility can then be based on AID's carefully monitored performance.

Congress can also increase the effectiveness of its albeit less direct oversight of multilateral development agencies receiving U.S. funding. For example, changes occurring at the World Bank offer Congress an opportunity to encourage reforms there. A major reorganization in which the Bank is improving its capability to do environmental analysis was partly the result of congressional pressure.

THREE CATEGORIES OF DEVELOPMENT ASSISTANCE FOR A RESOURCE-ENHANCING APPROACH

Three distinct though interrelated categories of aid or recipient groups offer substantial opportunities for development assistance to address the needs of resource-poor agriculturalists:

1. local level activities, including support for local institutions, households, and individual agriculturalists;
2. the formal agricultural institutions supporting agricultural development including those providing research, education, extension, and marketing; and
3. national policy formulation and implementation including assistance for the development of supportive national policies and of national capabilities to create, implement, and evaluate them.

After evaluating the general lack of success of U.S. efforts to support African agricultural development, most experts agree on the need to refocus on the "small farmer." General agreement also exists on the need to address all three categories listed above, but that U.S.-supported organizations have differing abilities to work with each of them.

Development Assistance at the Local Level

The common goal of most current assistance at the local level is to increase the food security of the farmer, herder, or fisher while setting the stage for further development (34,54). To do so it will be necessary to develop new technologies and make them available along with appropriate existing ones in order to increase agricultural production and income. This is a two-way process which allows agriculturalists to take advantage of opportunities offered by agricultural institutions and government policies while communicating their needs to make the institutions and policies more effective. However, in the majority of cases local level assistance provided by major donors has not been successful in supporting development because the assistance has not been appropriate to local conditions nor applied in a way that would be sustained by the resource-poor farmer (1,30,65,72). Two lessons have been learned from this lack of success. One is that assistance activities must work with technologies that are appropriate to local environmental and socioeconomic conditions (discussed in ch. 5). The second lesson is the need for farmer participation to ensure that assistance is appropriate to local conditions and that development started with external assistance will be maintained (7,19,41).

Major donor organizations (e.g., AID and the World Bank) have not been effective at working at the local level nor with local institutions whose membership includes resource-poor agriculturalists. But certain other U.S.-funded organizations have been more effective. These include: U.S. private and voluntary organizations and the Peace Corps. Both have become increasingly active in bridging the gap between local organizations and the major donors. At the same time, local African organizations and the rural non-farm private sector are also emerging as effective actors in their own right.

U.S. Private and Voluntary Organizations

An estimated 300 U.S. private and voluntary organizations (PVOs) had African programs and were carrying out 2,700 projects in 1985. About $460 million was spent by those PVOs, 60 percent of it from U.S. Government foreign

Photo credit: Redenius/U.S. Peace Corps

The U.S. Peace Corps, like U.S. PVOs and local African groups, provides assistance with local level projects such as this vegetable garden in Burkina Faso.

assistance (50 percent in emergency food aid and 10 percent in development assistance) (28). Under Section 123 of the Foreign Assistance Act of 1961, as amended, a minimum of 13½ percent of the funding for the six Development Assistance functional accounts, the Sahel Development Program, and International Disaster Assistance are to be made available for the activities of private and voluntary organizations. PVOs received $62.8 million from AID's Africa Bureau in fiscal year 1986, and in fiscal year 1987 they received an estimated $42 million (24). The decline in emergency needs and the recognition that relief alone would not solve the root causes of famine have led PVOs to increase their attention to long-term social and economic development, with agriculture being an important subset of that work.

PVOs are commonly considered to have several significant advantages and strengths appropriate to a resource-enhancing approach at the local level (18,28,47,55). These include their ability to:

- work with the poor under difficult conditions and help make public resources available to them,
- work with indigenous organizations,
- understand local conditions,
- address equity issues,
- work in regions where development has been neglected,
- use a participatory process,
- use a long-term approach,
- be flexible,
- work in small projects, and
- extend a proven technology (when favorable policy and infrastructural conditions exist).

Caution is necessary, however, in assuming that these general strengths apply to each individual PVO or PVO project given their tremendous diversity and differences from country to country and project to project even within a single organization.

These strengths, AID's difficulties in working with the resource-poor agriculturalists, and an increasingly politically active PVO community have motivated Congress to consider increasing the role of PVOs in U.S.-supported development in Africa. However, as their role is increased, certain common PVO weaknesses should be acknowledged and addressed (18,28,47). PVOs often:

- are unable to reach the very poorest,
- lack technical expertise,
- fail to address the role of women,
- lack innovation,
- depend too much on the continued presence of individuals capable of mobilizing the population,
- lack project replicability and sustainability,
- have poor or nonexistent project evaluations,
- lack wide-scale impact, and
- are difficult to coordinate because of their large numbers.

Some PVOs are making efforts to overcome these weaknesses. For instance, some are being linked with formal research organizations to overcome their lack of technical expertise. In this way, PVOs are involved in testing and extending technologies to farmers while transmitting needs and ideas back to the scientists. Also, AID has facilitated the work of PVOs in some countries by setting up quick-funding sources at the mission level, known as umbrella projects, that require less paperwork for small PVO projects. In conjunction with these efforts at increasing PVOs' effectiveness, there remains the more difficult task of evaluating individual PVOs on their actual abilities to support development at the local level. A further challenge is present in the growing abilities of African indigenous organizations. PVOs may need to play a more supportive role by supplying resources, training, and other assistance to such organizations rather than directly implementing their own projects.

The Peace Corps

The Peace Corps has volunteers and programs in 25 African countries (68). Its overall and Africa budgets have both increased steadily since 1980 (table 6-5). The Peace Corps' mandate is to support the personnel needs of developing countries (especially for meeting the basic human needs of the poor) with trained Americans. Additionally, its goals are to promote a better understanding of the United States within the developing countries and a better understanding of developing country's societies by the American people (Public Law 87-293 as amended). Its programs respond to locally identified needs, emphasizing individual training and strengthening local organizations (68). In Africa, the Peace Corps emphasizes agriculture, private sector development, health, and education.

With 25 years of experience in people-to-people work, the Peace Corps has come to be

Table 6-5.—The Peace Corps in Africa, 1980-87

Year	Obligations worldwide (millions $)	Obligations for Africa (millions $)	Volunteer years in Africa
1980	103.3	38.6	2,035
1981	104.7	38.8	2,048
1982	104.7	40.6	1,989
1983	108.5	40.9	2,114[a]
1984	115.0	43.6	2,086
1985	129.5	47.0	2,124
1986	124.0	46.3	2,236
1987[b]	130.0	48.8	2,175

[a] Estimate

[b] Data for 1987 are estimates and do not include data from the $7.2 million supplemental appropriation received in fiscal year 1987.

SOURCES: Agency for International Development, *Congressional Presentations*, fiscal years 1982 through 1988; Peace Corps, *Congressional Presentations*, fiscal years 1982 through 1988.

appreciated by the African governments seeking its help; many requests for volunteers remain unfilled. It has identified skills needed to work at the local level and developed the ability to train its volunteers in local languages and culture. Most volunteers work in conjunction with African government programs and are placed at the local level where they often provide links between national and local organizations. Recognizing the technological constraints facing agricultural development, the Peace Corps has made efforts to recruit an increased number of technically trained volunteers.

Because of these abilities, the Peace Corps may have an even greater role to play in enhancing low-resource agriculture. In addition to its direct work with resource-poor farmers and herders, it also is in the position to be an important intermediary between the larger donors; formal agricultural organizations; local organizations; and individual farmers, herders, and fishers. For example, AID is providing small-project assistance funds for local groups associated with volunteers. Such an approach increases the resources available to the local groups but it has a potential disadvantage in that it could change the Peace Corps' role (and the African perception of it) to a funder rather than a provider of skills and training.

The quality of the Peace Corps' agricultural work varies from country to country and program to program. The short-term nature of its 2-year volunteer tour and high volunteer attrition contribute to this unevenness as does the agency's lack of effective institutional memory. Short tours of service for staff add to these problems. High turnover rates, in part due to the short tours but also to other difficulties, have made long-term planning and implementation difficult.

The overall impact of the Peace Corps' work is difficult to judge because it lacks an internal formal evaluation process. African conditions are changing rapidly and it is not clear whether Peace Corps programs are keeping pace. Effective future work, based on actual strengths rather than anecdotal evidence, will require an improved evaluation system.

The Peace Corps' African Food Systems Initiative (AFSI) is an attempt to repond to some of these problems by developing long-term (5 to 10 years), localized approaches to food security in each country. The program includes col laboration with AID and PVOs. For example, AID has supported individual members of the Peace Corps AFSI programming teams. The Peace Corps has committed significant resources to AFSI and will need continued funding for its success. Currently, AFSI operates in Lesotho, Mali, Niger, and Zaire with a fiscal year 1987 budget of $1.9 million. During its first 2 years, fiscal years 1986-87, 162 volunteers were involved, with 99 of them beginning their tours in fiscal year 1987. The program is projected to expand to Guinea, Senegal, and the Central African Republic in fiscal year 1988. One potential weakness of AFSI, like that of the Peace Corps generally, is that evaluation has not yet become a well-defined, integral component.

Local African Organizations

Many donors over the past decade, have come to recognize that indigenous groups can be effective at the local level. Most often local groups have received donor assistance to carry out donors' activities. To some donors, however, local organizations are being seen as increasingly capable partners that can implement their own programs.

Despite this growing awareness, however, these groups' potential has been largely untapped, especially by the major donors who instead have focused on supporting more formal government agencies and institutions (7,18,19, 42). The African Development Foundation is not among the U.S. organizations included in these discussions since it is the subject of a separate OTA assessment. It is, however, one of the U.S. agencies attempting to maximize the role of indigenous organizations (66).

Local organizations (also known as local membership institutions or grassroots organizations) are diverse. Some are informal, self-help groups; others are formal and organized at the regional or national level. They may be organized along single interests lines to manage a common resource, such as water-use societies and pastoral associations. Or they may provide a single service as in the case of marketing cooperatives and rotating credit associations. They may be organized for multiple functions and act as indigenous voluntary development organizations comparable to non-African PVOs (7,19). Approximately 100 such groups from 18 countries in May 1987 formed the pan-African Forum of African Voluntary Development Organizations (FAVDO). FAVDO hopes to link these organizations and to provide help in identifying development needs and mobilize African and non-African support.

Local organizations can enhance the effectiveness of development assistance programs by increasing their relevance, cost-efficiency, and sustainability. These groups can be effective in transferring information on local needs and conditions to outside development agencies while also representing farmers to donors, the private sector, and government agencies. They can mobilize resources such as labor, management, and money for development work and thus reduce demands on overburdened government organizations and reduce the need for external support of recurrent costs. In addition, working through such groups allows donor assistance to reach more farmers. Sustainability can increase where group members are involved in the design and management of assistance activities since such involvement often leads to greater commitment to implementing the work and maintaining it once outside assistance ends (7,19,23,71).

Certain conditions for successfully working with local organizations are being identified. Local organizations can best support development if: they are involved in project decisionmaking; they retain a high degree of self-reliance and autonomy; their members and beneficiaries maintain a degree of control over the organization; and the organization can shift project activities to meet the needs of its beneficiaries (71). They cannot be successfully forced into existence or managed by donor organizations or national governments because their success depends on membership commitment. Their effectiveness can be destroyed, moreover, by attempts to co-opt them into larger bodies, by pushing them to exceed their capacities, using them only as implementors of donor activities, or by overfunding.

Large donors and national governments may find working directly with local and intermediary institutions discouragingly difficult (7). The formation and development of these groups is not predictable and takes time. Program funding needs are comparatively low, increasing the proportion of funding used in administration. It is often difficult for large donors working with local organizations to spend all their funds within a required timeframe (usually on an annual budget cycle). Also, significant donor resources are needed to identify and evaluate these groups. Despite these drawbacks, increased support for large donor organizations will be necessary as the number and abilities of these local groups increase and their needs outstrip the capabilities of smaller donors (e.g., PVOs) who presently support them (48). Large donors may also have a role in linking these organizations with formal agricultural institutions so that the formal institutions better address their needs.

The Afrkan Rural Non-Farm Private Sector

Though even more diverse and often more dispersed than local organizations, the rural non-farm private sector could have significant direct and indirect positive impacts on resource-poor agriculturalists. The non-farm sector can be defined as all economic activity apart from crop or livestock production. Data on these activities are sparse and country-specific, but it appears that the majority of rural non-farm enterprises are small (95 percent have fewer than five workers), have modest capital requirements and show seasonal fluctuations in output and labor demands (25).

Typically, 10-20 percent of rural employment (with a range from 3-73 percent) and 25-30 percent of rural income are derived from rural non-farm activity. Because non-farm earnings are converted to money more often than agricultural products, they constitute a large share of cash income, often 50 percent. Surveys have shown that 15-65 percent of farmers also have secondary employment in non-farm enterprises and that farm households devote 15-40 percent of their working hours to income-generating non-farm activities. These activities also provide women, especially in poorer households, with opportunities to earn income (25).

Besides offering rural employment and income, the non-farm private sector also provides the agriculturalist with agricultural inputs, markets for products, and consumer goods. The first forms a relatively weak market because of African agriculture's relatively small use of inputs but could increase if more appropriate inputs were made available and if credit systems were improved (25,32). Providing a market for products is the most significant of the three roles. Local processors and particularly distributors purchase a major share of commercialized produce in many areas. The market for consumer goods and services provided to farmers by the private sector is seen as an important stimulus to the growth of the rural non-farm economy both because of its potential high growth rate as farmers' income rises and due to the large amount of labor it could absorb with such growth (25).

Four means have been identified for supporting the development of non-farm enterprises. First, and most importantly, increasing agricultural productivity and income would increase agriculturalists' demand for goods and services while also providing secure food supplies for non-agricultural workers. Second, national policies can be redesigned to avoid discrimination against non-farm enterprises in such areas as credit availability, tariff structures, access to foreign exchange, licensing requirements, and restrictions on the goods or services they can provide. Third, direct assistance to non-farm enterprises can be provided in forms such as credit, technical assistance, and training in marketing and management. Evaluations have shown these types of programs to be cost-effective if they focus on one major constraint to the enterprises instead of trying to address all at once. Fourth, rural infrastructure (e.g., roads, water, transportation, and electricity) can be improved, though it is not yet clear in what sequence the infrastructure should be provided (25). Controversy exists over the attention paid to infrastructural development. Some see it as essential for increasing the adoption of new technology (11), but others argue against significant assistance for infrastructure because it may divert capital from agricultural production and often benefits urban areas more than rural ones (36). Some do not consider AID to have a comparative advantage in infrastructural work even though such projects have been used as an effective means to absorb sudden increases in assistance to a country (30).

The potential of the indigenous private sector in a resource-enhancing approach varies significantly across Africa and, therefore, the sector's needs for assistance vary as well. Much of the current private sector assistance provided by major donor organizations overlooks non-farm rural enterprises and little national policy reform work has been geared toward their support.

Major donor organizations have been directing most agricultural policy assistance at larger, more formal marketing and input supply services, such as government marketing boards and parastatals, sometimes with the purpose of turning them into private firms. Parastatals' roles are decreasing in many countries because of increasing budget deficits and these efforts by donors (21). Such privatization has contributed, in some cases, to increases in agricultural production (43).

Important to private sector assistance will be opening the marketplace to multiple private sector enterprises and not just the conversion of non-viable public monopolies and their replacement with private ones (2). In some cases the public sector may continue to be necessary to serve resource-poor farmers and herders in commercially unprofitable and geographically isolated locations. Private sector assistance needs to be monitored and evaluated as to whether benefits are being captured primarily by larger enterprises.

Development Assistance in Support of Formal Agricultural Institutions

The development and strengthening of African agricultural institutions (research, education, extension, credit, marketing organizations, etc.) is a second high priority category of assistance in a resource-enhancing approach. Supporting the development of agricultural institutions offers several general benefits. First, well-developed African institutions will be more efficient than external donors in providing direct services to agriculturalists. Second, development programs are more likely to continue after donor assistance ends if in-country institutions are capable of maintaining them. Third, sound national policies and good economic management can be encouraged and supported by donors, but their implementation and follow-through will primarily depend on the abilities of the African institutions. Fourth, the ability of recipient countries to absorb and use foreign assistance in part depends on the capacity of their institutions (71).

Agricultural development will depend on strengthening African institutions in such areas as research, education and training, policy analysis, and administration (38,46). Equally important for the development of low-resource agriculture will be the ability of these institutions to address the specific needs and constraints of resource-poor agriculturalists.

Support for staff training and other institutional development of agricultural institutions will require relatively high levels of long-term, stable funding usually available only from larger donor organizations. Cooperation and coordination among donors working with each individual institution and between institutions providing interlocking services to the same agriculturalists will also be essential.

Training

Training is a major focus of AID's efforts to strengthen African agricultural institutions. It provides training to African professionals through numerous programs in the United States, in the recipient country, and in other developing countries. Data on the total number of people trained in-country or in third countries are sparse, but the numbers are considerable because most AID projects contain a training element. From 1980 to mid-1987, 3,523 Africans received short- and long-term agricultural training in the United States, primarily at universities (59).

AID funds training in several ways. Individual bilateral projects programmed by the mission can have training components. Centrally funded programs overseen by AID's Science and Technology Bureau (e.g., the African Graduate Fellowship Program, the African Manpower Development Project, and the Sahel Manpower Development Program) also provide training. Finally, AID supports agricultural schools in Africa that provide training for faculty and students. As part of its 1985 "Plan for Supporting Agricultural Research and Faculties of Agriculture in Africa," AID is supporting seven schools of agriculture in Cameroon, Kenya, Zimbabwe, Uganda, Burkina Faso, Sierra Leone, and Lesotho (the first three receive high levels of support). In all seven cases, the actual training is being carried out by U.S. universities under contract to AID. The Africa Bureau spent between 4 and 7 percent of its agricultural portfolio on training (1979-87) (table 6-6). Data for overall AID African training expenditures are not available.

Several factors are important for such training to enhance low-resource agriculture. Assistance for training needs to:

- build increased understanding of the specific features and needs of low-resource agriculture,
- ensure that women receive adequate training opportunities and that men are trained in working with women's needs,
- provide as much training as possible in Africa,
- support changes in African curricula to ensure their relevance to African low-resource conditions, and

Table 6-6.—AID Funding for Agricultural Education and Training[a] in the Africa Bureau's Agriculture Portfolio[b], 1979-87

	1979	1980	1981	1982	1983	1984	1985	1986	1987 (est.)
Expenditures									
Total (millions $)	5.9	7.6	14.6	15.1	14.8	14.0	13.0	14.9	23.8
As a percent of total agriculture portfolio	5.0	4.3	6.0	7.7	6.2	5.6	5.3	4.9	4.9
Obligations									
Total (millions $)	14.1	14.4	14.6	20.4	17.4	12.7	14.5	16.6	21.1
As a percent of total agriculture portfolio	6.4	5.4	5.2	6.5	5.5	3.7	3.6	4.7	6.7

[a] These are funds for training individuals. A separate budgetary category contains funds for the infrastructural needs of training institutions.
[b] The agriculture portfolio includes Africa Bureau funding from DA and ESF. It does not include PL 480 funding nor funds used by other Bureaus.

SOURCE: U.S. Agency for International Development, Africa Bureau, *Agriculture and Rural Development: Functional Review FY 1978-1987*, July 1986, updated 1987.

- educate Africans at U.S. institutions able to provide suitable knowledge while supporting graduate and postgraduate research in Africa.

Questions have been raised concerning the relevance of AID-supported training to African conditions. Although U.S. assistance has led to large numbers of trained Africans, it has not yet had a major impact on the rural sector (26). AID relies heavily on U.S. universities, especially State agricultural schools, for training. Although the existence and abilities of these universities is one of the strengths of U.S. development assistance (30), there are also drawbacks. The majority of U.S. schools operate in ways not necessarily relevant to African agricultural needs (4,56). For example:

- Low-resource agriculture is not a focus of most U.S. schools.
- African technical needs often require different technologies and often focus on different crops than those used by U.S. agriculture.
- The resources a student has available and comes to depend on at U.S. universities may not be available upon return to an African institution.
- U.S. agricultural disciplines tend to be narrow, with little opportunity to engage in broader problem-solving work.
- U.S. schools generally provide few incentives for doing international work or for supporting long-term efforts.

Institution-Building

Support for agricultural training will not have its full impact if African agricultural institutions are not developed concurrently. At present, many trained Africans find their skills unused or underused because they have no institutional base from which to work. Therefore, support for building African institutions themselves is an important adjunct to training. Experts agree that the provision of institution-building assistance can be most effective if it:

- provides long-term support (for 15-25 years) combined with steady levels of funding;
- provides core funds for institutions to cover costs not met by funds from individual projects;
- develops incentives and provides funds for policymakers, researchers, and extension agents to do field work;
- links research, extension, educational, and policymaking institutions with one another and with local institutions;
- uses flexible approaches that can match changing local needs;
- supplies newly trained Africans with start-up funds and support for collaborating with senior scientists; and
- develops methods for institution-building that promote links between agricultural institutions and resource-poor agriculturalists.

The results of past donor attempts at institution-building have been mixed. The World Bank is among the most active donors in this type of program but evaluations of its work have been critical of its methods and results. Only 50 percent of the World Bank's agricultural projects achieved some degree of success in institution-building in 1985, a drop from the 63 percent success rate over the period 1979-84 (74). The Bank's institution-building objectives have often been tacked onto agricultural projects, taking a backseat to production goals and the need for rapid disbursement of funds. The needs of recipient institutions have not been well analyzed and foreign technical assistance has been used to circumvent institutional problems instead of working to solve them. Overall, the World Bank has not been effective at supporting development of agricultural institutions such as universities, research institutions, and co-ops nor has it been successful at linking farmer organizations with supporting institutions (71).

The World Bank recently completed a detailed analysis of ongoing African research and research needs which in part details the importance of long-term strengthening of African national research systems, universities, and training. Although this work makes it clear that research must address the actual conditions faced by the small farmers there is little recognition of the role farmers, their organizations, and their knowledge can play in supporting technology development and diffusion nor does it suggest a role for the World Bank in linking farmers, herders, and fishers to African national research institutions (77,78).

Photo credit: F. Botts/U.N. Food and Agriculture Organization

A resource-enhancing approach to African agriculture places a high priority on supporting African research institutions. This is a laboratory of the Burundi Ministry of Agriculture and Fisheries.

Nevertheless, positive changes in the World Bank's efforts can be seen in some of its work begun in the 1980s. A number of projects have begun with more thorough analyses of the recipient institutions' needs, with institutional development their primary goal, and with long-term training programs (71). The World Bank also has increased lending for African agricultural institutions providing research, extension, training, credit, and marketing services (34,71, 79). Despite these improvements, evaluation of the World Bank's East Africa portfolio found that promoting agricultural growth will require substantial additional investment in training, and in building and strengthening agricultural institutions. According to the study, major efforts are needed to increase institutions' capacities to provide a full range of services, and perform the data collection and analysis on which to base critical decisions (35).

AID is considered to have a comparative advantage in providing assistance for institutional development, although its work too has had only moderate success and its emphasis in this area is insufficient. For example, a recent evaluation of AID's work in six African countries found that 13 percent of assistance was spent on education and training while only 2.3 percent was spent in support of agricultural research (30).

AID has taken several steps to improve its ability to provide assistance for institution-building, especially agricultural research. The agency estimates that $55 to $60 million are spent annually for these purposes by all bureaus. This increased emphasis is shown by Africa Bureau funding (table 6-7). AID released its "Plan for Supporting Agricultural Research and Faculties of Agriculture in Africa" in May 1985 as another part of this greater emphasis on training and research institution-building. The plan focuses U.S.-supported research by directing the majority of AID's resources to 22 countries, 8 agricultural commodities, and a small set of

Table 6-7.—AID Funding for Agricultural Research and Research Capacity in the Africa Bureau's Agriculture Portfolio[a], 1979-87

	1979	1980	1981	1982	1983	1984	1985	1986	1987 (est.)
Expenditures									
Total (millions $)	10.4	16.2	25.8	26.6	29.5	29.1	30.2	37.8	51.0
As a percent of total portfolio	8.8	9.2	10.6	13.6	12.4	11.7	12.2	12.5	10.5
Obligations									
Total (millions $)	31.3	32.5	46.0	45.9	39.8	40.1	34.3	44.1	45.6
As a percent of total portfolio	14.3	12.3	16.4	14.7	12.7	11.6	8.6	12.5	14.4

[a] The agriculture portfolio includes Africa Bureau funding from DA and ESF. It does not include Public Law 480 funding nor funds used by other Bureaus.

SOURCE: Agency for International Development, Africa Bureau, *Agriculture and Rural Development: Functional Review FY 1978-1987*, July 1986, updated 1987.

research problems. For example, the plan emphasizes mixed crop/animal farming instead of assistance to pastoralists due to past failures in range management. In 8 countries that have relatively strong research capacity, assistance will support increased capabilities to produce technologies. The 14 other countries with lower research capacity are to be supported in developing their ability to import and adapt technology. In addition, research networks are to be supported that address regional needs, that support countries with the weakest research systems, and that provide links with the International Agricultural Research Centers. Currently AID is supporting work on all 8 commodities, and is active in 7 of 8 "technology generating" countries, and 13 of 14 "technology adapting" countries.

AID's approach to institution-building is based on its understanding of the importance of improving African technical capabilities; that successful technology development requires a long-term approach; and that farming-systems research is one way to bridge the gap between researchers and farmers, herders, and fishers. Overall, AID has developed a strategy that emphasizes small farmers, food crops, and increased donor coordination. Many of the promising technologies identified in this report are being supported by AID (53).

AID's research plan is an important step in focusing attention on the technical needs of African agriculture. However, the plan may be too narrow in several respects. The AID Plan, much like the World Bank's approach, does not address the role of the farmer in technology development. Farming systems research is presented less as a vehicle for farmer participation than as a means to ensure the acceptability of new technologies. Also, serious questions have been raised regarding AID's commitment to farming systems research. Another concern is the reduced number of commodities to be researched. While this reduction can help focus resources it also means that regionally important minor crops playing a large role in African nutrition and making up an important component of many farming systems may be neglected. Also, too little effort has been given to research and development of technologies for processing well-adapted tropical crops into desired food products (5). Parallel attention to research for livestock systems, fisheries and forestry, upon which many low-resource agriculturalists depend, has also been lacking.

A significant common weakness of much donor assistance to African agricultural institutions has been the failure to promote links to resource-poor agriculturalists. The lack of impact of agricultural assistance as a whole can be traced in part to a failure to develop technologies relevant to African agriculture. African extension agents find themselves with nothing to offer farmers and herders. Evaluations have shown that donor support for technology development has been inappropriate for resource-poor agriculturalists. Reasons for this inappropriateness include (6,14,40,72):

- failure to analyze if the technology was tailored to the needs of resource-poor agriculturalists, for example, by avoiding expensive inputs or minimizing risk;

- ignoring the importance of other farm operations, local cultural and ethnic factors, and the local environment;
- ignoring the effects of the new technology on recipients;
- ignoring gender differences and not ensuring female participation;
- a lack of farmer involvement and on-farm testing;
- an absence of multidisciplinary research;
- an emphasis on short-term projects; and
- failure to account for national policies.

If future technology development by African institutions is to avoid repeating these mistakes, attention must be paid now to how institution-building can be done in a way supportive of developing low-resource agriculture. Development organizations need to address this issue and draw together the expertise of the universities, the private sector, international agricultural research centers, and African institutions that have worked in this area.

An important part of drawing together this expertise will be an increased coordination of efforts. Coordination of research activity is particularly necessary to prevent duplication of efforts by the large number of donors, national governments, and networks involved in research. An example of increased coordination in research is the Special Program for African Agricultural Research (SPAAR), established in 1985 by 15 major donors to support coordination and strengthen African national research institutions. It has a small secretariat located at the World Bank and six working groups: regional research networks; promising technologies; an information system on donor-funded research; guidelines and strategies for building national research capabilities; forestry; and education and training (77,78). In addition, SPAAR supplies small grants to African scientists through the International Foundation for Science in Stockholm.

The International Agricultural Research Centers

Thirteen International Agricultural Research Centers (IARCs) located worldwide, with a combined budget in 1986 of $235 million, are supported by 39 national, multinational, and private donors under the auspices of the Consultative Group on International Agricultural Research (CGIAR). Each has responsibility for certain food crops, animals, or farming systems and all have programs concerning Africa. They are internationally staffed and independent of their host governments. Four are located in Africa: the International Institute of Tropical Agriculture in Nigeria, the International Livestock Center for Africa in Ethiopia, the International Laboratory for Research on Animal Diseases in Kenya, and the West African Rice Development Association in Liberia. Seven other centers have personnel stationed in Africa and two centers research African policy and research management issues. With increasing international attention on Africa, the centers have increased their African work, and about 50 percent of the CGIAR system's resources are now devoted to Africa. Questions have been raised, however, about the propriety of an organization with worldwide responsibilites spending such a large percentage on one region (29).

AID has funded the CGIAR system since its founding through contributions to core funding and through special projects. From 1978 to 1986, AID funded at least 25 percent of the system's annual core budget. U.S. core contributions peaked in 1986 at $46.25 million and declined to an estimated $40 million (21 percent of the core budget) in 1987 (60). The United States also supports specific projects at the centers. U.S. funding of such projects totaled $14 million in 1986 (10).

In addition to the CGIAR system there are approximately one dozen other international agricultural research centers. Those with relevance for African agriculturalists include the International Fertilizer Development Center, and the International Soybean Program, both in the United States, and the International Council for Research on Agroforestry and the International Center for Insect Physiology and Ecology, both in Kenya.

The CGIAR and non-CGIAR centers' work in Africa have had less than their anticipated

Photo credit: Donald Plucknett/Consultative Group on International Agricultural Research

Scientists from the International Center for Tropical Agriculture (CIAT) and the Rwandan national research system cooperate on bean research. Such collaborative work is important to increasing the benefits of research sponsored by the International Agricultural Research Centers.

impact on agricultural development. Recently, CGIAR has reevaluated its goals and research methods and has determined ways in which to increase the impact of its work (8,11):

- including multiple new crop varieties, each adapted to different local conditions, instead of one or two single "breakthrough" varieties;
- addressing farming systems and moving the location of research away from research stations to do so;
- modifying research goals for new technologies which reduce the farmer's risk in addition to increasing production; and
- strengthening African national research centers.

These new attitudes are reflected in the centers' increased outreach programs, increased work on farmers' fields, attention to African crop and livestock varieties, research on African farming systems, and attention to environmental sustainability. The centers are working toward an improved balance between field work and work done at the experiment stations. The effects of these changes are important also because national research institutions often adopt approaches used by the international centers (31).

While the CGIAR system claims to be increasing its attention to on-farm conditions, criticisms remain that centers have not fully implemented this shift. For example, concerns have been raised about the relevance of on-station work for the farmer. Some feel that too little effort has been made to grow diverse varieties in farmers' field (or under simulated farmer conditions). Plant breeders have not focused on ensuring that improved varieties provide stable yields throughout the area where they are to be grown and on ensuring that their resistance to pests is durable (5). A further constraint is the lack of commitment to including the farmer as a partner in research and even to talking with farmers and consumers to guide the setting of objectives early in a crop or livestock breeding program.

The issue of where to focus research is also unresolved. Arguments in favor of directing research to the most favored geographic areas to reap the quickest and most economical results contrast with arguments to increase research on the more marginal areas where large numbers of people live and raise their food (11,37). Disagreements between centers located inside and outside Africa over responsibility for specific commodity research, for example, maize, have also hampered the system's work and need to be resolved. Overall, the centers would benefit from stronger ties to African and non-African scientists through better communication and joint projects (5).

The CGIAR system has played an important educational role, providing training to about 6,200 Africans between 1962 and 1984 through short courses, degree programs, and post-doctoral work. This figure underestimates the actual number trained because it counts only those trained at the headquarters of each center (9). Training makes up about 12 percent of the funds CGIAR spends in Africa (29). However, training programs need to increase emphasis on training women who make up less than 10 percent of those trained by the system

(8). Training impact also would be improved if the centers' increased their collaboration with African universities (29).

The CGIAR system has recognized the importance of supporting the development of national research systems but it spends only 1.6 percent of its operational budget on such support (11). In addition, only a small part of its training has been related to institution-building at the national level. The International Service for National Agricultural Research was established in 1980 as the lead center in support of national agricultural research systems. Although its impact has not been evaluated, demands for assistance have outrun its capacity to respond. Institution-building is seen as a high priority for future CGIAR work (11), but questions remain regarding how much the system is willing to divert from its primary focus on research. The centers will remain important sources of agricultural research and training and have potential for support and strengthening national research institutions. However, donors' assistance to the international centers can complement but cannot substitute for directly supporting the development of national research systems.

Development Assistance To Support National Level Policy Reform

A third focus of development assistance in a resource-enhancing approach involves a wide range of programs that support African policy reforms at the national level. One lesson learned in the 1970s by donors was that assistance for local and institutional development can be offset by unsupportive and counterproductive national policies (33). Such policies have resulted from multiple factors but include a lack of attention to the needs of low-resource agriculture, over-investment in other sectors, and a dependence on export agriculture to finance other efforts. National governments and donors have contributed to these errors.

AID and the World Bank have placed increasing importance over the past decade on the need to adjust national policies (tables 6-8 and 6-9), concentrating on a set of macroeconomic and agriculture-specific policies identified as constraints to broad economic development. They and other donors supply large amounts of nonproject lending, cash, and commodity aid to encourage national governments' agreement to institute changes such as (76,57):

- reducing overvalued exchange rates and restrictions on imports,
- reducing government expenditures,
- removing biased tax and trade policies,
- increasing farmgate prices that are below national and world markets,
- reducing the monopolies of both state marketing boards that maintain low commodity prices and inefficient agricultural input distribution organizations,
- increasing opportunities for the private sector,
- cutting subsidies for costly agricultural inputs used primarily by the richest farmers, and
- cutting consumer food subsidies.

Theoretically, these policy reforms could help resource-poor farmers significantly by ending policies that are favorable to large farms and encourage food imports, and by increasing farm prices, investment in infrastructure, and the efficiency of the market (30). It is not clear, however, if current policy reform efforts are having these impacts. Reform is often focused on broad macroeconomic changes and, in some cases, has not yet been tailored to adjust agricultural policies more specifically (16). Where changes have occurred in agricultural policy their impacts on resource-poor farmers are unclear.

The swift rise in funding for policy reform has outpaced efforts to evaluate its impacts. Programs have been based on hypotheses regarding responses to policy changes rather than on data of actual responses. This lack of microeconomic work in the agricultural sector has left macroeconomic analysis inadequately linked to actual farmer behavior (34). The deficiencies of microeconomic analysis and lack of adequate evaluation of policy reform's impact on resource-poor farmers leads to concerns over how quickly reform has become a priority for de-

Table 6-8.—AID Funding for Policy Reform and Economic Stabilization in the Africa Bureau's Agriculture Portfolio[a], 1979-87

	1979	1980	1981	1982	1983	1984	1985	1986	1987 (est.)
Expenditures									
Total (millions $)	7.9	39.6	57.3	18.0	60.5	69.7	79.5	108.4	170.9
As a percent of agriculture portfolio	6.7	22.5	23.6	9.2	25.4	27.7	32.1	35.9	35.2
Obligations									
Total (million $)	26.9	57.9	47.9	60.7	81.4	124.3	172.9	123.3	90.2
As percent of total agriculture portfolio	12.3	21.9	17.1	19.5	25.8	36.0	43.2	34.9	28.5

[a] The agriculture portfolio includes Africa Bureau funding from DA and ESF. It does not include Public Law 480 funding nor funds used by other Bureaus.

SOURCE: U.S. Agency for International Development, Africa Bureau, *Agriculture and Rural Development: Functional Review FY 1978-1987*, July 1986, updated 1987.

Table 6-9.—World Bank Policy Reform Lending to Sub-Saharan Africa, 1984-87

Fiscal year	Commitments to Sub-Saharan Africa	Reform lending[a]	Reform lending as a Percentage of commitments
	($ millions)		
1984	2,338	819	35%
1985	1,598	193	12%
1986	2,582	1,210	47%
1987	2,285	1,261	55%

[a] Includes IDA and IBRD lending.

SOURCE: World Bank, Special Office for African Affairs, 1987.

velopment assistance. Results from initial evaluations have not yet confirmed the theoretical benefits for resource-poor agriculturalists and in some cases have proved that the initial assumptions used are wrong (17). While some evaluations show that policy reforms in conjunction with other conditions (e.g., good weather) can lead to increases in national crop production, it remains difficult to link reforms specifically with increases in resource-poor agriculturalists' income and production. Where such links can be made, it appears that the minority of better-off small farmers are the primary beneficiaries (22,69,70).

Within policy reform activities, the basis for the current emphasis on pricing has also been questioned. Real prices for food and/or export crops were already increasing in many African countries in the 1970s and declining real food and export crop prices were not common (20). Also, price reforms may have less impact on total production and food security in reality than they do in theory. Depending on the circumstances, farmers often sell commodities for a higher or lower than official price in private or informal markets. In response to raising the price of one commodity, farmers may grow more of that commodity but less of other important crops. Price policies are important but require careful microeconomic analysis on a country-by-country and even local basis. Blanket pricing policy changes thus do not seem to be a wise strategy for the entire continent.

Initial results show that reform may actually hurt segments of the rural population including resource-poor agriculturalists. Macroeconomic reforms have been encouraged by donors without full regard to the negative effects on poor people's income and welfare (especially children) caused by deflationary effects on the economy and reduced government spending (12). In addition, increases in food prices also may have had adverse impacts on the poorest farmers. For example, about 40 percent of the farmers in Mali are net food buyers who perform non-farm work to be able to afford enough food. Increased food prices have forced them to spend more of their income on food (17). Attention to how reform affects farmer income could help avoid such negative impacts. Reform needs to be more concerned with maintaining economic growth to provide increased jobs and incomes. It should also include provisions for supporting programs (e.g., nutrition or health) for vulnerable populations (12,73).

An important component for the success of reform programs is the relationship between donors and national African governments. It is commonly believed that reforms require donor pressure and stringent conditions to ensure African governments' compliance. However, such pressure can constrain actual reforms and replace real change with complex agreements and paper gains (3). Instead of this pressure, a more cooperative approach between donors and African governments could take advantage of African knowledge, and be based on the fact that governments will support reforms that are in their own interest, and that maintaining reform requires African support.

Few African governments currently have the capacity to gather and analyze data necessary to plan reforms, to implement them, and then to modify them as conditions change. But the continued responsibility of expatriates for these tasks makes policy reform expensive, less sustainable, and sometimes inappropriate to local conditions. While donors have been increasing their support for policy reforms, their support to improve African capabilities to participate in these decisions has not kept pace (33, 38). For example, AID's Africa Bureau expenditures for building African policy capabilities reached a high in 1981 and have declined since, although overall spending for reforms has continued to increase (58). The World Bank has come under strong criticism for failing to draw on and further develop the analytical capability of African governments as well (35).

Opportunities exist to use policy reform programs to enhance low-resource agriculture. As noted earlier, reforms can help end discrimination against small, private, rural producers and enterprises. Donor assistance has already increased government attention to the agricultural sector in general. An example of positive donor assistance to reform programs is being carried out by the United Nations Development Fund for Women (UNIFEM) which has begun sending consultants to round-table discussions organized by the United Nations Development Program (UNDP) where African governments and donors discuss policy reforms. UNIFEM's participation at those round tables has led to increased data collection on women's activities, promoted women's needs in policy decisions, and helped governments and donors find ways to include women in their work (39).

AID AND A RESOURCE-ENHANCING APPROACH

The U.S. Agency for International Development (AID), as the principle U.S. implementing agency for economic assistance, would have lead responsibility for incorporating an approach to enhance low-resource agriculture into U.S. foreign assistance. The broad roles of AID in implementing such an approach are discussed in the first part of this chapter. Some more specific questions regarding AID's Africa strategy and the institutional factors that affect its ability to implement a resource-enhancing approach are raised here.

AID's Strategy

Under AID's current strategy[3] for African development, a resource-enhancing approach could be initiated, though its implementation would require some changes and more clarity in AID's activities. Agricultural development is one of AID's top three priorities in its strategy for African aid (57) and support for agriculture comprises over 50 percent of the Africa Bureau's budget (table 6-10). With agricultural development a priority, several areas are already receiving attention that would be part of a resource-enhancing approach:

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[3] AID's strategy for development in general and specifically for Africa is set out in three documents:

- the 1984 *Africa Bureau Strategic Plan* (51),
- the 1985 *Blueprint for Development: The Strategic Plan of the Agency for International Development*, (54) and
- the 1986 *U.S. Assistance Strategy for Africa 1987-1990* (57).

- policy reforms favorable to farmers,
- agricultural research,
- linking research to farmer needs through farming systems research,
- training African researchers and providing support for African research organizations, and
- attempting to relate natural resource and agricultural issues.

But whether AID activities actually will support low-resource agriculture depends, in part, on how successfully AID can address certain specific issues, including: participation, sustainability, local institution building, support for women in agriculture, reducing risk, and the technical needs and labor constraints facing farmers. AID has identified the importance of these issues in several cases, but has been less effective in implementing its findings. For example, the 1984 *Africa Bureau Strategic Plan* highlights the importance of local participation in development activities, including agricultural research, but does not incorporate this conclusion into the report's agricultural objectives. The 1985 *Blueprint for Development* again identifies the need for local involvement to help ensure successful development but does not include it when discussing agricultural development specifics. The other issues are treated similarly; they are recognized as being important but information is lacking on how AID could make them integral parts of its development activities.

AID's strategy papers do not acknowledge that local resources can provide important opportunities. While AID's overall strategy assumes that local resources can be used more productively (i.e., reforms in agricultural policies can stimulate increased production), it does not focus on direct support for developing and making improved use of those resources.

Of additional concern, AID's strategy documents have attributed less importance to certain of these issues over time. For example, local participation and sustainability, while mentioned in earlier reports are not included in the 1986 strategy. A 1978 agricultural development policy paper and a 1981 Africa Bureau food sector assistance paper address many of these issues but they are no longer explicitly contained in AID's most recent strategies (49,50).

To a large extent, these issues have been replaced by an emphasis on policy reform and economic stabilization. Central to AID's current strategy is the concept that accelerating economic growth is the best means to support African development. Economic growth, accomplished by increasing income, is seen as the best means to eliminate the extremes of poverty and to meet basic human needs. The tacti-

Table 6-10.—AID Funding for Agriculture in the Africa Bureau's Budget, 1979-87

	1979	1980	1981	1982	1983	1984	1985	1986	1987 (est.)
Expenditures									
Total (millions $)	118.2	175.7	242.8	195.9	237.8	251.5	246.9	302.1	485.7
Agriculture portfolio as percent of Bureau budget	69	63	63	50	47	52	53	54	56
Obligations									
Total (millions $)	218.9	264.8	280.9	311.9	315.4	345.5	400.6	353.3	317.1
Agriculture portfolio as percent of Bureau budget	69	64	60	50	51	50	48	50	59

SOURCE: Agency for International Development, Africa Bureau, *Agriculture and Rural Development: Functional Review FY 1978-1987*; updated July 1987.

cal mechanisms to reach accelerated economic growth are primarily macroeconomic and sector-specific changes in African national policies. Under this view, U.S. development assistance principally should be used to support and encourage African policy reforms while helping to stabilize the economy (e.g., through balance of payments' aid) so that reforms can be carried out.

As policy reform has become central to AID's strategy, other concerns have received less direct attention. Low-resource agriculture cannot develop without supportive policies, and failures in agricultural development have been due partly to flawed national policies. But, as already discussed, policy reform that is not well-linked to supporting low-resource agriculture may divert the benefits of development funding to other groups and may indeed be harmful to low-resource agriculturalists.

AID's Operations

The ability of AID to implement a resource-enhancing approach will depend not only on the clarity and appropriateness of its strategy but also on its operational capabilities. Past OTA work has identified a set of well-known constraints affecting AID operations (box 6-2). Besides these constraints (which need to be dealt with by AID), several promising trends in AID's operations may affect AID's future ability to address low-resource agriculture. They include:

- increased decentralization of decisionmaking to the field,
- a shift to longer term support and greater flexibility, and
- support for sustainability of activities and improved use of evaluations.

Increased Decentralization

AID's recent moves towards decentralization have given field missions increased authority to make and implement decisions. AID field personnel give the agency a comparative advantage over donors who do not have permanent field offices (30). Field staff gain on-the-ground knowledge and can have the day-to-day interactions with African policymakers and implementors necessary for collaborative decisionmaking. AID has attempted to cut paperwork requirements by giving missions increased authority over project approval. At the same time, the number of new projects has been reduced. AID also has increased average staff tours by 8 to 9 months and increased the use of foreign nationals in an attempt to maintain continuity. Short tours of duty are still the norm in Africa, however, and increased rewards may be necessary to encourage staff to stay longer in the posts in Africa that they view as less desirable.

Decentralization's potential contributions to a resource-enhancing approach are jeopardized, however, by concurrent personnel cuts and an attrition rate that exceeds hiring. Staff levels (including direct hire staff and foreign nationals) dropped 19 percent between 1981 and 1985 (61). Mission staff in the Sahel countries of Western Africa were cut by 25 percent in 1985 (67). Fewer personnel make it difficult for missions to carry out the detailed work necessary to address local conditions and to consider alternative programs (30). Technical staff have been cut the most and those remaining face the problem of being overworked and unable to make use of their technical skills or to update them. Evaluation activities have been particularly hard hit by staff reductions.

Shift to Longer Term Support and Greater Flexibility

AID has stated that its activities need to be carried out over longer periods of time and has now provided for project commitments of up to 10 years as well as for multiple extensions of shorter projects. Longer project commitments will be necessary particularly for successful agricultural research and the development of African institutions.

To a lesser extent, AID is also recognizing the need for more flexible implementation. Lessons learned from planning and implementing past projects and programs have led to calls for less pre-planning and more flexibility to change activities during project implementa-

Box 6-2.—Constraints on AID's Operations:—Lessons From the Sahel[1]

The challenge for future development efforts in Africa is to move to new modes of assistance that are more consistent with the nature of the region and the long-term goals of food security, environmental stabilization, and economic growth. The United States can continue to play a key role in this multinational development effort if it can incorporate the past decade's experiences into a more effective strategy. However, the Agency for International Development's (AID) effectiveness in applying the lessons of the past decade face constraints in four areas:

- the ambiguity of some AID policies and strategies,
- internal institutional characteristics of AID,
- the sometimes adversarial nature of AID's relationship with Congress, and
- the lack of agreement about the role of development assistance in overall U.S. foreign policy.

These constraints can be illustrated by examining AID's role in the multinational development effort in the Sahel region of Africa. After 10 years of assistance, AID's Sahel strategy has undergone much change in attempts to improve on failures. The most recent strategy statement incorporates many of the past decades' lessons: it places high priority on agricultural research and production, policy reform, health and family planning, training, infrastructure, conservation, and environmental protection. In addition, it calls for coordination among all donors. However, AID's strategy is at times ambiguous and its implementation sometimes is not consistent with the past decade's lessons and existing congressional mandates for foreign assistance. For instance, the changing focus toward policy reform, institutional development, and infrastructure—although consistent with the lessons learned—could signal a retreat from direct assistance to the poor, depending on how that focus is implemented. Despite the high priority stated for agricultural research, AID has no Sahel-specific research strategy. AID has not seriously addressed the issues of effective farmer participation or given adequate attention to the specific role of women in Sahelian production, processing, and distribution systems. Although the United States is the largest single donor of food aid in the Sahel region, there is little effective integration of food aid into overall assistance strategies.

AID's effectiveness in implementing its strategy also is constrained by internal institutional characteristics. One basic problem is that the numbers and skill levels of AID's staffing in the Sahel have not been commensurate with the level of U.S. commitment. Although French language and Sahel-specific technical skills have improved, they are still inadequate. The proportion of managers to technicians is high and too few personnel have appropriate skills in agricultural and environmental sciences, macro- and micro-economic analysis, and human resource development. The use of outside contractors, particularly from U.S. universities, has increased the talent pool, but quality is still uneven, turnover is high, and institutional learning is limited. Sahelian staff are often underused and AID contact with beneficiaries and counterparts is often inadequate.

Another problem is that AID's program and project design systems are cumbersome, slow, inflexible, and often directed toward short-term, physical objectives rather than longer-term development goals. Sahelian input, be it governmental or local, is often *pro forma*.

An additional institutional constraint affecting AID's performance in the Sahel concerns AID's relationship with Congress. Congress played an important role in the original U.S. commitment to the Sahel and has continued a high level of interest and support. Nonetheless, aspects of the Congress-AID relationship actually constrain the attainment of foreign assistance goals. For instance, congressional policy mandates to AID under the Foreign Assistance Act and other legislation are cumulative and without priority. While each may be desirable in itself and the impact of many themes (e.g., basic human needs, the environment, women in development, child welfare) has been at least partially effective, their number and frequency of changes hamper the development of consistent, long-term strategies. Consequently, these mandates sometimes are not taken seriously. In another area of con-

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[1] As part of the assessment of Low-Resource Agriculture in Africa, OTA in 1986 released a special report addressing U.S. assistance to the Sahel, *Continuing the Commitment: Agricultural Development in the Sahel*, OTA-F-308 (Springfield, VA: National Technical Information Service, August 1986.) This box summarizes the conclusions of that work concerning AID's operations.

Box 6-2.—Constraints on AID's Operations:—Lessons From the Sahel[1]—(Continued)

cern, procurement and financial controls are often unrealistic relative to African realities, and they do more to increase costs, create delays, and tie up AID and Sahelian management time than to accomplish their intended purposes. In addition, extensive congressional oversight—and sometimes over-attention to management detail like requiring notification of minor project funding changes—not only increases paperwork, it restricts the agency's flexibility to respond to evolving needs and opportunities.

The role of foreign assistance within U.S. foreign policy creates a fourth set of constraints for development assistance goals. The Sahel Development Program, for example, was born of the U.S. commitment to humanitarian concerns and a vision of long-term social and economic development. Yet it is not uncommon for short-term foreign policy objectives (e.g., political or commercial objectives) to conflict with this long-term perspective. Increased bilateralism, the use of conditionality with respect to political stances rather than development performance, and assistance tied to U.S. commercial interests all act to reduce the effectiveness of U.S. commitments in the eyes of Africans and other international donors.

tion. Critics argue that excessive pre-planning leads to problems because plans may be over 4 years old before being initiated or there may be a reluctance to change pre-planned activities despite significantly changed circumstances (14). "Rolling designs" have been proposed as an alternative. In these, an activity, though still planned in advance, can be changed by its implementors to respond to local capabilities and constraints (41). Under a rolling design, on-going contact with recipients is used to monitor the need for changes and continuous reevaluation is used to modify the activity accordingly. In addition, the rolling design may help overcome problems caused by AID's structural separation of design and implementation where implementors may be faced with activities designed by others and unsuitable for the evolving conditions in which they work.

Support for Sustainability of Activities and Use of Evaluation

AID has increased its attention to ensuring that development activities will continue once donor assistance ends. The prior AID Administrator, M. Peter McPherson, dubbed sustainability one of the "twin engines of development," along with economic growth. AID, like other donors, has had difficulty in making its projects and programs sustainable (14). This is in part due to operational problems (e.g., African and U.S. staff turnover and the short time period of assistance) which interrupt building indigenous management ability, but it is also due to a failure to provide sustainable technologies for resource-poor agriculturalists. Increasing the sustainability of AID's work will necessitate more effective support for institution-building, coupled with a better linking of supported institutions with the needs of low-resource agriculture.

AID has also been strengthening its information and evaluation systems since the early 1970s (30) and it can go farther in this direction. Two problems still plague this work. First, until an AID-wide data system is created that includes the Africa Bureau, the central bureaus, and the missions, it will not be possible to determine in full how much money is being spent to support agricultural development in Africa and how it is being spent. This problem is particularly acute for Public Law 480 local currency funding. Data currently available in different publications commonly are contradictory.

Second, and more important, too little use is made of evaluations when designing new work. For example, a review of AID's livestock program in Kenya between 1960 and 1984 found that the work failed to take advantage of lessons learned by the British and instead introduced technology without regard to the local environment or existing herding systems. When the AID projects began to fail, evaluations noted the need to address these two points. Yet this information was not used in the development of later livestock projects and these also failed, leading AID to drastically curtail its livestock work in Kenya. Part of the reason for poor design was the pressure to obligate an existing budget quickly, but more important was AID's failure to draw on past evaluations to improve future work (16). AID's moves towards decentralization; longer and more flexible support; and increased attention to sustainability, information systems, and the improved use of evaluation will all need to be reinforced if the agency is to play a more effective role in a resource-enhancing approach to African agricultural development.

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Part II:
Promising Technologies

Technology alone is not the answer to Africa's need for food security, but it can play an important role in equipping the continent to meet the challenges ahead. Chapter 5 looked generally at the opportunities available to use technology to enhance low-resource agriculture in Africa. It concluded that the technologies offering the most promise for contributing to the food security of resource-poor farmers and herders share some common characteristics: they are technically and environmentally sound, socially desirable, economically affordable, and sustainable.

By meeting this broad spectrum of conditions, a technology or technology package not only stands to be scientifically successful (that is, it effectively increases production, reduces degradation, inhibits losses, or otherwise helps meet food production needs), but it is more apt to be socially acceptable. A technology cannot have a significant impact in the long term if it is not acceptable to and adopted by the people who must use it.

Using the concepts outlined in this report, OTA identified a range of technologies that offer promise to improve food security in Africa. These technologies meet a variety of needs, from improving soil and water management to reducing post-harvest losses. The list is illustrative, not comprehensive. Chapters 7 through 11 examine these promising technologies, which fall into five general categories:

- technologies to improve the use of soil and water resources,
- technologies to improve cropping practices,
- technologies to improve crop and livestock genetics,
- technologies to improve the use of animals, and
- technologies to reduce losses.

Chapter 7

Improved Use of Soil and Water Resources

CONTENTS

Page
Soil and Water Management 161
  Summary 161
  Technologies To Increase Water Availability 162
  Technologies To Deal With Excess Water 165
  Potential 168
  Problems and Approaches 169
Improving Soil Fertility 170
  Summary 170
  Organic Fertilizers 171
  Inorganic Fertilizers 174
  Potential for Improving Soil Fertility 175
  Problems and Solutions 177
Small-Scale Irrigation 178
  Summary 178
  Gravity Diversion Systems 180
  Water-Lifting and Pumping Systems 181
  Potential 184
  Problems and Approaches 185
Chapter 7 References 187

Box

Box *Page*
7-1. Handpumps 183

Figures

Figure *Page*
7-1. Contoured Microcatchments to Control Soil Erosion and Water Runoff 163
7-2. Three Types of Microcatchments 164
7-3. Simple and Inexpensive "Fanya juu" Terraces 166
7-4. Increased Maize Yields in an Alley Cropping System Using Prunings From *Leucaena leucocephala*, a Nitrogen Fixing Tree, and Varying Rates of Nitrogen Fertilization 176
7-5. Response of Maize to Nitrogen in Different Climatic Zones 177

Tables

Table *Page*
7-1. The Effects of Plowing and No Tillage on Soil and Water Loss 168
7-2. The Effects of Mulching With Crop Residues on Water Runoff and Soil Erosion 168
7-3. Conservative Estimates of Biological Nitrogen Fixation Rates for Different Fixers 171
7-4. Effect of Manure and Commercial Fertilizer on Sorghum Yield at Saria, Burkina Faso 176
7-5. Estimates of the Distribution of Small-Scale Irrigation Technologies in Africa 179
7-6. Distribution of Modern and Traditional Irrigation in Sub-Sahara Africa 184

Chapter 7

Improved Use of Soil and Water Resources

SOIL AND WATER MANAGEMENT[1]

Summary

Africa's lands are under pressure to provide increased production to feed the continent's growing population. To meet this increasing need, farmers have shortened fallow periods on lands already in use and they have expanded cultivation onto lands of marginal productivity. The result is that many agricultural lands are now showing signs of widespread environmental degradation (36,72). Unchecked erosion is just one type of degradation and it can lower the productivity of crops and rangeland by reducing the availability of water, nutrients, and organic matter (64,80). Severe soil erosion has already reduced crop yields in some areas and continued erosion will be a major obstacle to achieving food security (76).

Reversing Africa's environmental decline will be costly. To gain perspective on the cost of addressing soil erosion, it is useful to examine the U.S. situation. The U.S. Federal Government has spent at least $15 billion to finance an array of soil conservation programs since the 1930s. Yet soil erosion continues to be a problem in the United States (32,38), and what success there has been is attributable primarily to national policies that encourage farmers to take high-risk lands out of production. Programs that reduce today's production to increase tomorrow's would not be popular in most African countries given existing food shortages.

Thus, solutions to Africa's environmental problems will have to focus on conservation measures that increase, or at least do not reduce current production significantly. Resource-poor farmers and herders would find it difficult to absorb the additional costs that may arise from implementing conservation measures. Since good conservation practices often benefit all segments of the population, government and private organizations also must be prepared to assume responsibility and costs for regenerating and maintaining a healthy resource base.

The following discussion has been organized according to whether the technologies are used primarily to increase water availability or to deal with excess water. Recession farming, microcatchments, building bunds and planting on the contour, and tied ridges all deal with increasing water availability. Drainage, terracing, minimum tillage, mulching, and other soil-conserving vegetation practices deal with excess water. Note, however, that while it is convenient to group technologies according to their primary function, a technology frequently serves multiple purposes. Mulching, for example, helps deal with excess water as well as reducing water runoff. In the process, it also controls soil erosion. Moreover, it is an effective way to increase soil moisture, improve soil fertility, and reduce weed problems. In addition, while the discussion of technologies for increasing water availability emphasizes the arid/semi-arid zone, seasonal water shortages can occur in any zone including the humid lowlands. Similarly, excess water and resulting soil erosion can be a problem even in arid areas during the heavy storms of the rainy season.

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[1] This material is based primarily on the OTA contractor reports prepared by Rattan Lal, International Institute for Tropical Agriculture, Ibadan, Nigeria; Lawrence A. Lewis, Clark University, Worcester, MA; and W. Gerald Matlock, Desert Agricultural and Technology Systems, Inc., Tucson, AZ (app. A).

Improving the natural resource base is an essential step not only to ensure the well-being of the vast rural population, which can seldom afford to purchase inputs such as fertilizers and irrigation, but also to open the door to changes that make greater use of external inputs possible when they become affordable. Africa is less able than other regions to pay the expense of conservation programs, yet it can least afford to ignore natural resources conservation. The technologies discussed here are among the most efficient and affordable means available for managing soil and water resources for the resource-poor farmer.

Technologies To Increase Water Availability

Recession Farming

In this traditional practice, crops are grown on saturated floodplains as the land becomes workable after annual floods. As the flood water recedes, farmers use planting sticks to make shallow holes up to 1 meter apart as sites to plant seeds from several kinds of crops. The mixture of plants that emerge rely on flood water stored in the soil.

The flood recession system works well for crops that have a short growing season such as many varieties of sorghum and millet. Only heavy clay-rich soils in low areas are suitable for this type of farming because they are flooded long enough to absorb sufficient water and have the physical conditions to retain it (48).

Recession farming is used throughout Africa wherever possible because it is an efficient and productive system. It is common along major rivers as well as on the margins of temporary ponds and lakes that line tributaries (48). It is particularly important in West Africa, where the availability of water along the Senegal, the Volta, and Niger Rivers contrasts sharply with the otherwise arid conditions typical of the region's rainfed farming.

Benefits of recession farming to resource-poor farmers may be undermined by other development interventions to manage water. In particular, construction of large-scale dams that eliminate annual flooding downstream can seriously interfere with recession farming. These impacts seldom seem to be accounted for in calculating costs and benefits of large-scale programs. It may, however, be possible to reconcile these conflicts better and sustain future benefits of recession farming. For example, a controlled artificial flooding of the Senegal River is being attempted to enable farmers to continue recession farming in conjunction with developing new large-scale irrigation systems (21).

Water Harvesting Microcatchments

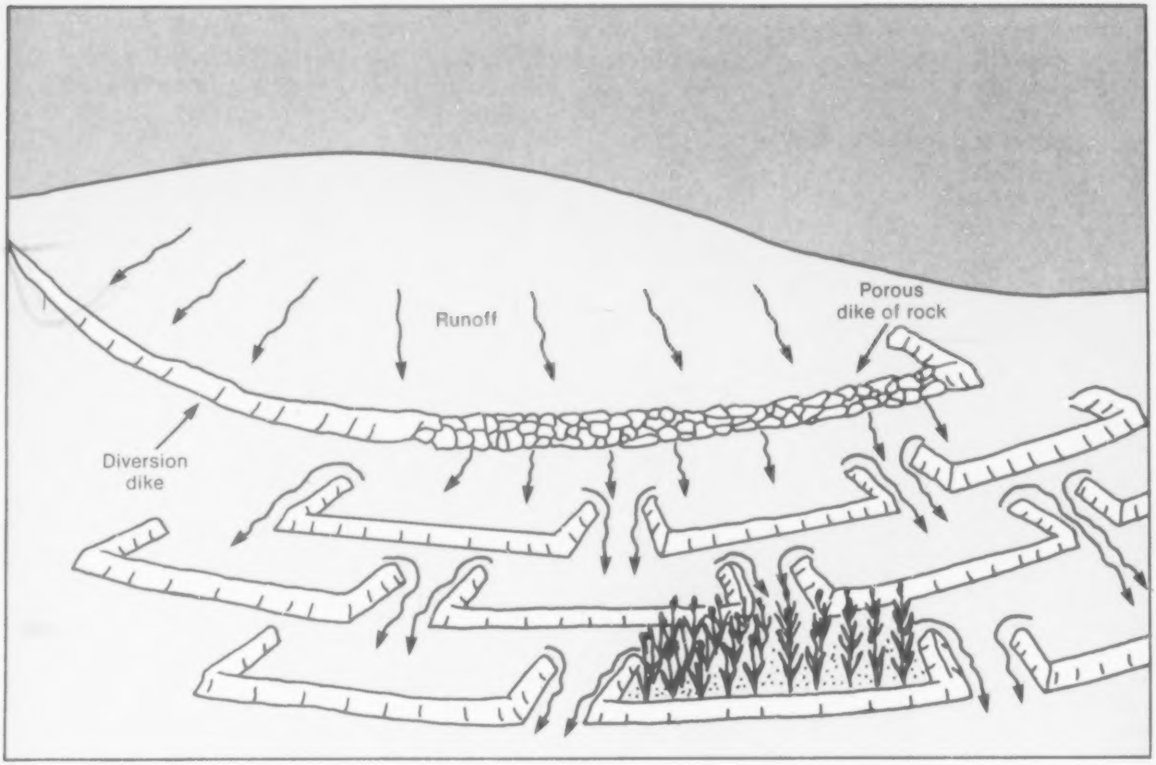
With these techniques a portion of land serves as a catchment area to produce runoff used for growing crops on the remaining land and for meeting human and animal water needs (11, 16,61,70). One approach uses modified furrows in which normal row spacing of crops is doubled, with the space between the rows sloped toward the plants. Excess runoff may be caught in a reservoir and used for supplemental irrigation.

Microcatchments a few meters in size are also excellent conservation measures (75). They can be placed on the contour to form an overlapping network that conserves both water and soil (figure 7-1). Where it is difficult to determine the contour, small microcatchments in the form of Vs or half-circles can be positioned to catch runoff (figure 7-2).

As with all technologies that concentrate rainfall, care must be taken to ensure that too much water does not collect during heavy rains. Provisions can be included to allow excess water to escape safely and thus provide protection against potentially severe erosion.

Water harvesting microcatchments have been introduced into several places in Africa: Cape Verde, Burkina Faso, Kenya, and Niger (61,73). The Peace Corps and several private voluntary organizations (PVOs) have promoted their use

Figure 7-1.—Contoured Microcatchments to Control Soil Erosion and Water Runoff



SOURCE: J. Tabor and B. Djiby, "Soil and Soil Management for Agriculture, Forestry, and Range in Mauritania," Mauritania Agricultural Research Project II, supported by the U.S. Agency for International Development (Tucson, AZ: College of Agriculture, University of Arizona, April 1987).

because the techniques are relatively inexpensive and individual farmers decide to use them.

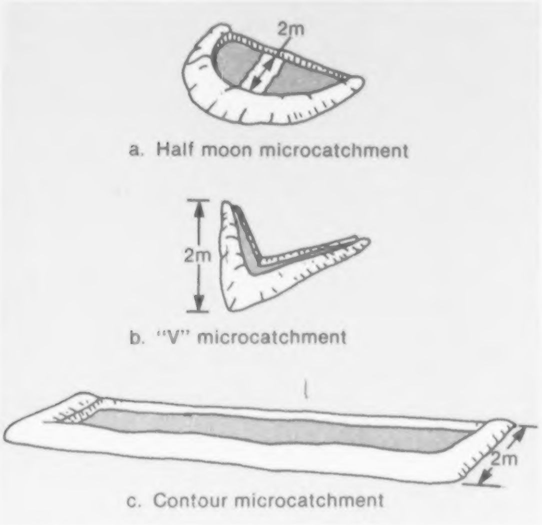
Building Bunds and Planting on the Contour

Planting crops in rows that follow the land's contour slows runoff and enhances infiltration (22). When ridges or bunds—embankments of rock or soil—are built to follow the contour of the land, the areas above and immediately below the barrier store more than normal amounts of soil moisture.

Crops can be planted on the contour on gentle or steep slopes, although in steep terrain provisions must be made to allow excess water to escape during major storms to prevent the entire system or hillside from being washed out. For example, cross-dikes can be used to confine washout, or spillways can be included at regular intervals to carry away excess water (48).

Bunds, on the other hand, are only feasible on gently sloping land. Large-scale, dirt bunding projects in Burkina Faso have increased crop yields and brought long-term soil conservation benefits (24). Stone-pile bunds used in the Yatenga plateau of Burkina Faso are even more promising. By introducing an inexpensive and simple device for determining the contour—a transparent hose attached at both ends to poles marked at half-centimeter intervals—Oxfam was able to improve on the tradi-

Figure 7-2.—Three Types of Microcatchments



a. Half moon microcatchment

b. "V" microcatchment

c. Contour microcatchment

SOURCE: J. Tabor and B. Djiby, "Soil and Soil Management for Agriculture, Forestry, and Range in Mauritania," Mauritania Agricultural Research Project II, supported by the U.S. Agency for International Development (Tucson, AZ: College of Agriculture, University of Arizona, April 1987). m = meter

tional practice of using lines of rocks to slow runoff. The new bunds trap topsoil, organic matter, and seeds, and they have been successful in helping revegetate the barren, encrusted wasteland that now covers an estimated 15 percent of this area (26,89).

Tied Ridges

Tied ridges are a variation of the microcatchment approach for trapping and holding water. Again, ridges are built to follow the land's contour, but in addition, the furrows between ridges are linked by cross-ties (small dams) to create closed microbasins 1 to 5m long (see photo). The cross-ties are kept lower than the ridges so they act as spillways in the event of heavy rainfall. The small basins retard runoff so water has more time to infiltrate, and soil water storage is increased. This practice is particularly effective in areas not subject to high-intensity rains, on freely drained soils, and on gentle slopes.

Tied ridges often have been introduced in conjunction with fertilizers, resulting in significant yield increases. For example, research stations in Burkina Faso showed increases of 1,000 kg/ha for maize, 930 kg/ha for sorghum, and 570 kg/ha for millet using a tied ridge/fertilizer combination (23,68). However, on-farm trials in the same area only produced increases of 10 to 40 percent of research station results, and at these low levels the additional labor requirements discouraged use of the technology (49, 68). Recent work by the International Institute of Tropical Agriculture (IITA) and the Semi-Arid Food Grains Research and Development (SAFGRAD) project suggests that a mechanical ridge-tier, using animal traction, adds little to farmers' labor and can increase yields substantially (65). Purchasing and maintaining animals can be a problem, however. Animals must be strong enough to work at the beginning of the rainy season, yet most will be undernourished from having just endured the dry, "hungry" season.

Even when built properly, tied ridges are susceptible to excess water buildup from heavy rainfalls. Rushing water can break over a succession of ridges causing deep rills or gullies. Under these circumstances, runoff control needs to be augmented with other practices such as drainage improvements or terracing.

Tied-ridge technology was introduced into West Africa in the 1950s and is being actively researched (65). The technology is also present in the drier parts of eastern and southern Africa, including parts of Malawi, Botswana, and Tanzania (13,69). The technique's heavy labor demand has restricted its use in all of these areas, but this constraint should be lessened with the advent of the IITA/SAFGRAD mechanical ridge-tier or similar devices. The increased soil moisture that results from tied ridges reduces the economic risks associated with purchase of commercial fertilizers, and fertilizer use, in turn, contributes to yield increases that can help pay for the cost of this combination of technologies.

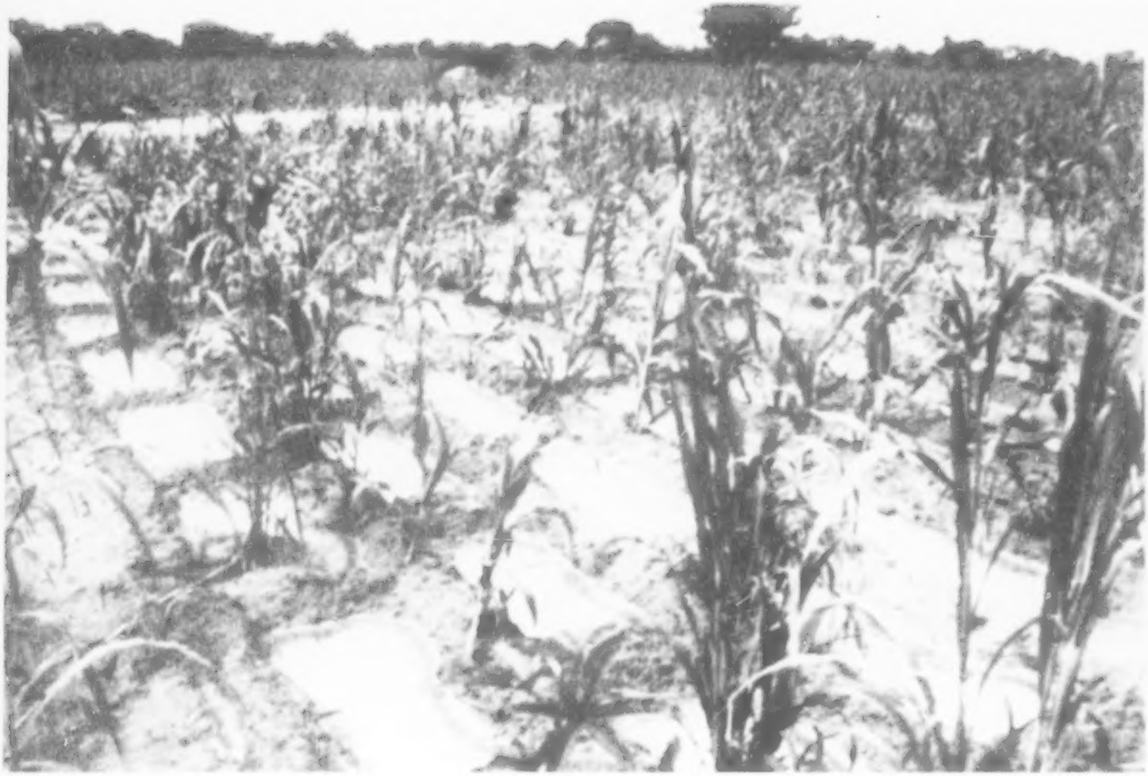


Photo credit: D. Woods Thomas/Purdue University

Tied ridges trap rainwater in this West African millet field.

Technologies To Deal With Excess Water

Drainage Practices

Soils require drainage either because a high water table exists or because a relatively impermeable subsurface layer retards water infiltration, so the soil above the impermeable layer becomes saturated. Saturated soil is poorly oxygenated and prohibits root development for most crops.

Subsurface drains, such as tile pipes, are an effective technique for lowering the water table. They are rarely used in Africa, however, because they are expensive and difficult to install. Open drains are common because they are less expensive and easier to build. However, they have many disadvantages including:

- reducing the area available for production,
- harboring weeds and rodents,
- requiring high maintenance, and
- creating favorable conditions for numerous waterborne diseases if stagnant water remains in them.

Open drains used on slopes can create an additional problem: if they are not lined or vegetated, or if poorly designed, they can be a catalyst for erosion and gully formation. In addition, problems worsen if the diversion channel is not large enough to handle major storms. In practice, most drains are underdesigned for a multitude of reasons, including: poor rainfall records, lack of space, high costs, and shortage of technical personnel to design and survey the drains properly. Therefore, erosion control using drainage is often ineffective. In fact, drains can aggravate problems because failed structures can allow sheet erosion to worsen into gully formation.

Water-saturated soils also can be due to excessive rainfall which infiltrates the surface layer but is trapped by an impermeable layer below. Under these circumstances it is important to reduce the amount of incoming surface water. Diversion bunds or ditches, built on a slight diagonal to the contour, can be used to intercept runoff and divert it at a non-erosive velocity to a suitable disposal point (74).

Proper drainage can increase the availability of arable land substantially. In Rwanda, for example, where rural population densities are high, artificially drained lands along valley bottoms are widespread and contribute significantly to the country's food production. In addition, because water tables remain close to the surface during the drier seasons, these zones often remain in production when adjacent lands are dry and idle (41).

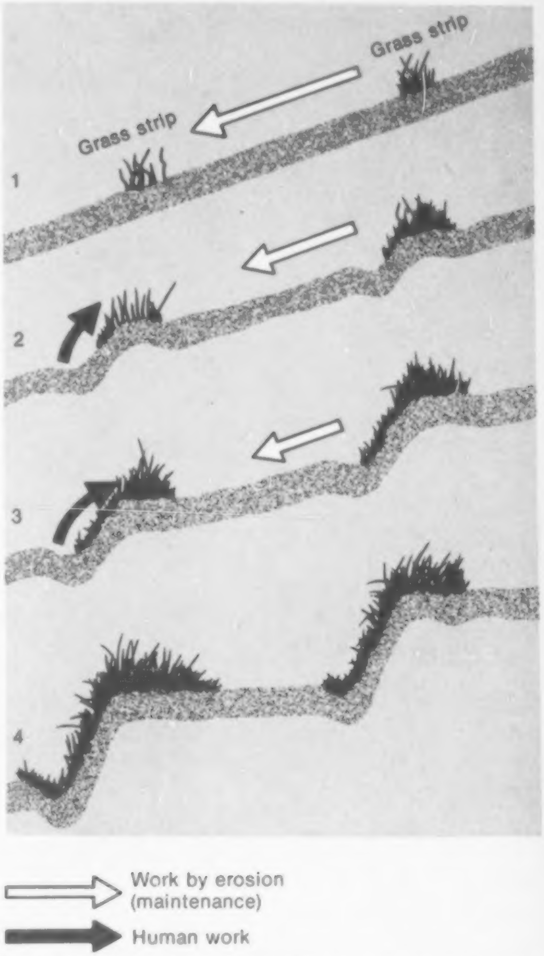
Terracing

Terracing agricultural land is one approach to slowing water runoff. It is important in humid areas to prevent excessive infiltration leading to mass movements of saturated soil. Thus, adequate drainage must be provided in terrace design.

Figure 7-3 shows an inexpensive and simple way to build a terrace:

1. leave vegetated strips of noncultivated land spaced across the slope between cultivated areas;
2. build a cutoff drain immediately along the lower edge of the noncultivated strip; and
3. allow erosion on the upslope part of the field and deposition along the edge of the vegetated strips to create terraces over a 5- to 6-year interval (86).

Figure 7-3.—Simple and Inexpensive "Fanya juu" Terraces



SOURCE: Larry Lewis and Leonard Berry, *African Environments and Resources* (Boston, MA: Allen Urwin, 1987).

One place where terraces have reduced soil erosion is in the Kenyan Highlands, where they are termed "fanya juu." More importantly from the farmers' perspective, however, is that they also have increased crop yields. For instance, in Machakos, Kenya, maize production increased 50 percent when terraces were installed. This increase probably resulted from the combination of soil saved and water and nutrients retained by terracing (40). Such substantial increases are essential to balance the construction costs of terraces and the planting space they take up.

"Fanya juu" terraces are not new to Kenya. During the colonial period a large number of such terraces were built, often using forced labor. Largely as a backlash, the terraces were either destroyed or left to deteriorate by the people after Independence. However, encouraged by funding from a Swedish development agency, farmers have revitalized "fanya juu" terracing in certain areas and many farmers have continued these efforts after external funding ended. This suggests that the benefits now accruing to farmers are attractive enough to justify the labor needed to build and maintain the terraces. The Kenyan government has only needed to provide technical assistance to align the terraces. Unfortunately, "fanya juu" terraces can be built only where topsoil is abundant, and these areas are few. Labor requirements are considered too costly to construct and maintain these terraces in most areas (41).

Minimum Tillage, Mulching, and Other Soil-Conserving Vegetation Practices

These practices—all of which achieve their benefits through the presence of an organic cover on the soil—are among the most effective methods of conserving water and reducing soil erosion (36,37,39,41). In contrast to engineering methods, soil-conserving vegetation practices require minimal soil manipulation.

Maintaining adequate cover is important particularly at the start of the rainy season in the humid tropics and always important in areas of steep slope (> 15°) (12). Where slopes exceed 15 degrees, vegetation and engineering methods, such as terracing, need to be integrated for effective soil erosion control (41). Some areas, however, are more valuable if left in natural vegetation. Steeply sloped watersheds, for example, may provide more important services than would be gained by converting them to agricultural land.

Soil-conserving vegetation practices should be emphasized as the first approach for managing excess water given the general constraints on capital, labor, skills, institutions, and infrastructure existing for most resource-poor farmers. However, these practices inevitably involve trade-offs for the resource-poor farmer.

Minimum tillage, sometimes called conservation tillage, involves seeding through crop residue or sod without plowing. Plowing and other forms of cultivation break up the soil and temporarily increase water infiltration while lowering run-off. However, soon after being tilled, soil structure generally breaks down, decomposition of organic matter accelerates, and erosion potential increases(6). Minimum tillage is an effective tool against this erosion. By leaving a cover of vegetative material, the soil is less susceptible to wind and water. This technique also allows farming on steep slopes that are severely erosion-prone. For example, minimum tillage maize can be grown on a slope of 15 percent while allowing erosion of substantially less than 1 mt/ha (table 7-1) (27,36).

Minimum tillage should be encouraged as a substitute for plowing throughout African humid areas. In addition to controlling soil erosion, the practice lowers the maximum soil temperature, helps maintain high levels of organic matter, and reduces the need for labor inputs during the planting season (36). Herbicide requirements for weed control are high, however, and these chemicals sometimes are not affordable or accessible to resource-poor farmers. Heavy herbicide use raises further concerns regarding environmental and human health. Plowing in arid areas sometimes is more appropriate than minimum tillage because plowing increases infiltration in compacted soils with low organic matter content (36,46,58).

In minimum tillage systems, crop residues left behind from the previous season's harvest act as a mulch and can reduce water run-off and soil erosion dramatically (table 7-2) (36). However, crop residues in Africa, such as cereal stalks, often are needed for fodder, cooking fuel, or building material. The amount of mulch can be increased by managing the crop sequences and combinations or growing a cover crop specifically for this purpose. Mulch material also can be brought in from elsewhere and added

Table 7-1.—The Effects of Plowing and No Tillage on Soil and Water Loss[a]

Slope	Water runoff (mm)[b]		Soil erosion (ton/ha)[b]		Maize grain yield (ton/ha)	
	No tillage	Plowed	No tillage	Plowed	No tillage	Plowed
1%	11	55	0.0	1	4.5	3.6
5%	12	159	0.2	8	4.5	3.8
10%	20	52	0.1	4	4.0	3.6
15%	21	90	0.1	24	3.6	3.0

[a] Maize production at the International Institute of Tropical Agriculture, Ibadan, Nigeria. The season's rainfall (1973) was 526 mm.
[b] mm = millimeters; ha = hectares

SOURCE: Rattan Lal, "Managing the Soils of Sub-Saharan Africa," *Science*, vol. 236, Mar. 29, 1987, table 6, p. 1073.

Table 7-2.—The Effects of Mulching With Crop Residues on Water Runoff and Soil Erosion[a]

Slope	Water runoff (mm)[b]		Soil erosion (ton/ha)[b]	
	No mulch	Mulch	No mulch	Mulch
1%	412	0	9	0.0
5%	483	11	134	0.2
10%	303	21	137	0.2
15%	375	20	96	0.7

[a] Residues were applied 6 ton/hectare and the season's rainfall was 1022 millimeters.
[b] mm = millimeters; ha = hectares

SOURCE: Rattan Lal, "Managing the Soils of Sub-Saharan Africa," *Science*, vol. 236, Mar. 29, 1987, table 4, p. 1073.

to the field. Alley farming (see ch. 8), for example, may serve as a source of tree prunings that can be used for mulch and other purposes (36). Animal manure is another source of mulch. Although obtaining and transporting large amounts of manure can be a serious obstacle, the benefits can be a key factor supporting a farmer's decision to incorporate animals in the farming system.

Potential

The technologies discussed above could contribute to the sustainable use of soil and water resources. Although they commonly offer only a modest economic advantage in terms of increased production, especially during years with normal rainfall, they offer the great advantage of helping to stabilize production during years of too little or too much rainfall. Equally important is their long-term value in safeguarding the soil resources upon which future production will be based.

Water availability can be increased and made more reliable in virtually all areas that suffer from inadequate or erratic water supply. A survey based on rainfall and soil data suggests that as much as one-half of the area in many arid and semi-arid countries could use water harvesting technology (1). During years of normal rainfall these practices will improve the soil but may not bring any significant increases in yield. However, in years with below average rainfall they can help stabilize production because they have improved the moisture retention capacity of the soil. Crop yields from a water harvesting scheme in Burkina Faso were little more than yields obtained from traditional farming methods in 1982 when rainfall was about 450 mm. But in 1983, a drought year, the yield from fields using the technology was 48 percent greater than on neighboring farms (61). In the Lake Region in Tanzania, results from 14 trials between 1939 and 1946 showed that cotton, maize, and sorghum yields in ridged plots were almost always higher than in flat cultivated plots. The only exceptions, 1942 and 1945, were years of above-average rainfall. Yields from ridged plots in the drier years were impressive, especially considering that the unridged plots suffered crop failure (6).

These soil and water management technologies are relatively non-capital-intensive. Labor, for the most part, can be supplied by farmers during the off-season. Men, women, and children all can be involved in their construction, operation, and maintenance.

These technologies also can be used to enhance the intensive production provided by small home gardens. For example, preliminary data collected in Cape Verde show that an intensive garden of only 500 square meters with adequate water for two crop seasons per year will provide all the food required for a family of six. Developing and storing water supplies to accomplish this is a realistic goal (48). Home gardens traditionally have been tended by women to produce vegetables, spices, and other specialty crops. Improved water management technologies will reduce the time spent carrying water from distant sources, and the surplus food and specialty crops produced can be sold in local markets, thus increasing the income available to women and their families.

Problems and Approaches

A major challenge facing agricultural development in Sub-Saharan Africa is the ability of poor rural populations to meet their immediate food needs without undermining the long-term sustainability of the resource base that supports them. The soil and water conservation technologies described above would involve investing resources today in order to provide continued benefits in the future. This trade-off could be very difficult for African farmers, as well as African governments, faced with immediate needs for short-term survival.

While these problems are difficult to solve, some successes exist. For example, the Government of Rwanda and international conservation groups are cooperating to protect mountain gorillas and farmers' water supplies despite pressure to clear forested park land for additional settlement. The Parc National des Volcans was Africa's first national park, established in one of the poorest and most densely populated countries.

One-half of the park's original area already had been cleared for agriculture by 1969 when deforestation was proposed for approximately one-half of the remaining area. Analysis suggested that clearing would provide land for only 3 months' population growth under the most optimistic conditions. Further, studies showed that economic arguments existed for retaining the forested watershed, which provides clean water supplies for human and livestock consumption, keeps water tables high enough to enable local farmers to harvest multiple crops, even in the dry season, and which will be needed to ensure the full productivity of a proposed hydroelectric dam downstream. Also, the park and the mountain gorillas have stimulated a major tourist industry, contributing approximately $1 million in annual revenue, Rwanda's third largest source of foreign revenue and the fastest growing economic sector (50,87).

The proposal to clear additional land was abandoned in 1979 and several steps were taken to ensure the park's protection. Guards were hired to stop wildlife poaching and gorillas were habituated to humans so that tourists could be assured of seeing them. Also, long-term education projects began to gain the support of local people. Thousands of Rwandans were educated regarding the significance of the park via posters, calendars, radio broadcasts, and slide and film presentations (87).

Ultimately, the success of such projects depends both on ensuring that local people share in the benefits, as well as the costs, of conservation measures (e.g., by taking part in the tourist industry) and on providing alternatives for the people who would have gained land or income from other proposals. AID's work in Latin America suggests that poorer farmers can successfully implement conservation projects when these factors are accounted for (85).

Increased attention by development assistance agencies could speed development and implementation of small-scale water and soil management systems, but the approach would need to be long term. Site-specific adaptive research is needed to diffuse these practices successfully. One project entitled Technologies for Soil Moisture Management, funded by AID's Science and Technology Bureau and implemented through the U.S. Department of Agriculture's Agricultural Research Service, is expanding its efforts in Africa and is planning on-farm trials to study the economic viability of several of these technologies (53). Pilot projects are needed in several locations to adapt the technologies to the different agroecological conditions of Africa. Newsletters, other publications, seminars, and workshops, for example, could link regional pilot projects and practitioners of the technologies (10). Improved and expanded extension efforts also will be required. Short courses could be provided in-country to increase the number of professionals and paraprofessionals skilled in using small-scale soil and water management methods (47).

These conservation technologies stand to benefit from the more general research needs discussed in chapter 5. For example, farming systems research is needed to improve understanding of factors determining technology adoption rates. Another specific need is for a land classification system that can be used in tropical Africa. The Land Capability Classification developed for conditions in the United States (33) often has been applied to tropical areas (20), but generally is not suitable for African conditions. For example, the system classifies all lands with slopes greater than 7 degrees as unsuitable for cultivation. This is too restrictive for Africa, where manual cultivation is common and erosion potential is lower as a result. Other aspects of Africa's farming systems, precipitation patterns, and soil attributes differ greatly from conditions for which the U.S. land classification system was devised (41). An applied land use classification system for Africa could build on the U.S. Department of Agriculture's efforts to adapt the Soil Classification System and map Africa's soils (8) but also should take advantage of indigenous methods of classifying the land according to its uses (75).

IMPROVING SOIL FERTILITY[2]

Summary

Low soil fertility is a major constraint to improving African agricultural productivity (78). Fertility levels vary throughout the continent, but they are generally low because of extensive weathering of the soils (7). Traditional farming systems relied heavily on fallow periods to restore the land (36,59). But this practice is less viable now in much of Africa because of human population increases. Consequently, more intensive management is necessary to replenish soil fertility. Soil fertility can be maintained or improved through a variety of practices that optimize the benefits of internal farm resources. For example, the soil and water management technologies discussed previously can conserve nutrients by reducing soil erosion and by reducing leaching of nutrients below crops' root zones.

Organic fertilizers also can improve or help maintain soil fertility. For example, legumes and other biological nitrogen fixers typically can add some 100 kg of nitrogen per hectare per year (ha/yr) in the tropics (18). And nutrient losses after harvest can be reduced by as much as 50 percent when crop residues are left in place or returned (82). Manures are another option for adding nutrients to soils. Nutrients are released gradually through the decomposition of plant and animal wastes—an advantage in the wet tropics, where soluble nutrients are quickly leached. Plant and animal wastes also increase soil organic matter, which can be as important as nutrients themselves. Soils rich in organic matter maintain water effectively and have favorable soil structure, thereby promoting root development. Vesicular-

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[2] This material is based primarily on the OTA contractor report prepared by P.L.G. Vlek, A.U. Mokwunye, and M.S. Mudahar, International Fertilizer Development Center, Muscle Shoals, AL (app. A).

arbuscular mycorrhizae, a group of naturally occurring fungi that live in association with plant roots, are not fertilizers *per se* but they are another biological means by which nutrient availability can be increased. These fungi improve plant roots' ability to withstand drought and to absorb phosphorus from the nutrient-poor soils (82).

The use of inorganic fertilizers, as well as organic fertilizers, will be necessary if Africa is to feed itself. Currently, inorganic fertilizers—phosphate rock and more highly processed commercial fertilizers—are used at very low levels in Africa (82). Numerous economic and institutional obstacles are responsible for the current low consumption rates and deter rapid increases in commercial fertilizer use.

Development assistance could continue in its efforts to encourage increased use of commercial fertilizers, but it also could increase emphasis on organic fertilizer alternatives. These techniques are less capital-intensive than those that rely heavily on commercial fertilizers and substitute labor and management information for cash (15). An important long term benefit of these practices is that they increase soil organic matter—and soil organics act as sites to hold nutrients—thereby increasing investment returns from applying phosphate rock and more highly processed commercial fertilizers when available.

Organic Fertilizers

Biological Nitrogen Fixation

Biological nitrogen fixation (BNF) is the process by which microbial organisms reduce or "fix" atmospheric nitrogen into a form usable to plants. Three categories of processes can be distinguished based on the biology of the micro-organism:

1. Symbiotic: the micro-organism and the host plant form an intimate relationship beneficial to both partners; for example, *Rhizobium*-legume symbiosis and *Azolla-Anabaena* symbiosis.
2. Associative: the micro-organism is non-symbiotically associated with root systems.
3. Free-living: the micro-organism is completely independent; for example, free-living bacteria or blue-green algae.

These processes are universal and their benefits accrue to farmers without active intervention. However, management decisions by the farmer concerning crop selection and farming practices affect the extent of these benefits. The quantities of nitrogen fixed vary widely, depending on crop and environmental conditions, but the benefits of biological nitrogen fixation in tropical regions can be substantial (table 7-3). It is generally accepted that nitrogen fixation of around 100 kg/ha/yr can be expected from the majority of grain and forage legumes. Higher levels are possible for *Leucaena*, other woody perennials, and forage legumes with a continuous growing season (18).

In addition to the nitrogen provided through fixation, mulch from leguminous trees and shrubs returns accumulated nitrogen to the soil. Deep-rooted trees like *Acacia* extract nutrients that are otherwise beyond the reach of annual crops, while stabilizing the soil and reducing soil erosion (see ch. 9). These nutrients then en-

Table 7-3.—Conservative[a] Estimates of Biological Nitrogen Fixation Rates for Different Fixers

Nitrogen fixer	Rate (kg N/ha/yr)[b]
Grain legumes	50-150
Forage legumes and cover crops	100-250
Tree and shrub legumes	75-150
Anabaena-Azolla symbiosis	50-100
Non-symbiotic and associative nitrogen fixation	10-30
Free-living fixers	5-15

[a] Considerably higher rates than these have been reported in the literature, but OTA considers these rates more realistic for on-farm conditions.

[b] kg N/ha/yr = kilograms nitrogen per hectare per year.

SOURCES: J. Halliday, Director, Batelle-Kettering Laboratory, Yellow Springs, OH, personal communication to OTA, 1987; P. Vlek, et al., "Soil Fertility Maintenance in Sub-Saharan Africa," contractor report to the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December, 1987); J. Halliday and P. Somasegaran, "Nodulation, Nitrogen Fixation and Rhyzobium Strain Affinities in the Genus Leucaena," *Leucaena Research in the Asia-Pacific Region*, edited by the Canadian International Development Research Center (Ottawa: IDRC, 1983).

rich the topsoil as fallen leaves decay and as manure from leaf-fed animals is recycled. The soil is also enriched indirectly when trees, rather than crop residues and manure, are used as the source of fuel for cooking and heating needs.

The biologically fixed nitrogen available for crops may be less important than other benefits from BNF. When leguminous crops are harvested, between 60 and 90 percent of the accumulated nitrogen is taken from the system. In grain legumes, for example, the majority of fixed nitrogen is harvested with the seed, which on average contains twice the level of nitrogen than the plant as a whole (19) and makes a critical nutritional contribution to people's diets. Probably no more than 60 percent of the nitrogen left in organic residues after harvesting is available for the next crop, or 6 to 24 percent of the total nitrogen accumulated by the plant (18). Thus, the principal benefit from legumes that are harvested arises from the fact that they can be grown without the addition of nitrogen fertilizer. Crops that are able to fix nitrogen are "free" in terms of outside nitrogen demand. The surplus they leave for the following crop is a small but significant bonus to the resource-poor farmer. In contrast, "green manures"—nitrogen-fixing plants specifically grown to be plowed or hoed into the soil rather than harvested—can provide the majority of nitrogen needed for the subsequent crop. Leguminous trees and shrubs also can be used as a valuable tool in reforesting degraded lands (18).

It would be difficult to find a farmer or herder in Africa who does not reap the benefits of BNF in one form or another. Scattered native leguminous plants grow on abandoned land, and many traditional farming systems include a leguminous crop in the rotation (e.g., millet/cowpea and maize/cowpea in West Africa and maize/bean in East Africa). However, resource-poor farmers and herders do not receive maximum benefits from BNF. The greatest potential seems to be in developing:

- legume-based pastures for fodder production (see ch. 11);
- increased use of leguminous trees in agroforestry systems, such as alley cropping (see ch. 8);
- legume-based cropping systems; and
- increased use of *Azolla* in rice fields.

Advanced research on related topics, such as gene transfers, primarily is occurring at institutions outside Africa and, if successful, may in time find its place in the African context. Current BNF technology is principally related to inoculating plants with effective strains of *Rhizobium*, selecting and multiplying the micro-organisms, and manufacturing and applying the inoculants. Little inoculant is used in sub-Saharan Africa. However, some inoculated legumes, such as soybeans, have been introduced from other areas and are routinely used by commercial farmers in Zambia, Kenya, Zimbabwe, and Rwanda (82).

Azolla is a genus of small aquatic ferns that are capable of forming symbiotic relationships with a blue-green cyanobacteria, *Anabaena azollae*. The fern provides nutrients and a protective leaf cavity for the *Anabaena*, which provides fixed nitrogen for the fern. The *Azolla/Anabaena* association thrives in the aquatic conditions present during rice production—conditions that prohibit the growth of most legumes. The fern grows extremely quickly, doubling in weight every 3 to 5 days. When it is incorporated into the soil, this "green manure" is a rich source of organic matter, nitrogen, and other nutrients, many of which might otherwise have been washed away. In addition to acting as a soil amendment, *Azolla* suppresses weeds, can be used as fodder, and is even used to a limited extent for human consumption in Asia (45).

The use of *Azolla* in rice production, a well-established practice in Vietnam and China, is only in an experimental stage in Africa. The West African Rice Development Association has led in the research and extension of this technology, but it still is only used by a few African farmers (81).

Vesicular-Arbuscular Mycorrhizae

Mycorrhizae are beneficial species of fungi that penetrate plant roots resulting in a symbiotic relationship between these fungi and the host plant that can lead to increased crop yields. One type—the vesicular-arbuscular mycorrhizae (VAM)—are the most important group of these fungi for agronomic crops. Maize, cowpea, and onion, for example, cannot take up phosphorus from low-phosphorous soils unless their roots are infected with VAM. The VAM act as extensions of the plant's root system, providing an increased surface area for absorbing nutrients. This is particularly useful for the more immobile nutrients such as phosphorus, zinc, and copper. Mycorrhizal activity is enhanced by the high temperatures, low moisture, and low phosphorus-conditions encountered in much of semi-arid and tropical Africa (34).

VAM, like BNF, benefits farmers and herders in Africa through natural processes without deliberate management. Improvements in mycorrhizal technology will help farmers make efficient use of phosphorus from all sources in Africa's phosphorus-poor soils, however. Unlike BNF, though, it has proven difficult to culture VAM on artificial media, and therefore it is best done using roots of susceptible plants (52). It is difficult, though, to obtain pathogen-free inoculum in quantity with these methods. Additional work needs to be done before VAM technology will find its entry into African agriculture. It seems that VAM is not likely to reduce the need for organic and inorganic fertilizer but is more likely to play a role in concert with those other inputs to improve efficiency of phosphorus use (82).

Manure

Manuring refers to the recycling of organic material so that the nutrients in animal and plant wastes are used to improve soil quality. Although this section focuses on the use of livestock wastes as manure, several other types exist. "Night soil," human excrement, is an important source of soil nutrients in densely populated Asia, but its use is culturally unacceptable in much of Africa. Household litter containing organic wastes such as food byproducts also is a source of nutrients and its use in African gardens could be increased. Crop residues can improve soil fertility in addition to offering other benefits (ch. 7). "Green manures" are crops grown specifically to be plowed back into the soil. They sometimes consist of grasses, but since they more typically are legumes, they were discussed in the preceding section on biological nitrogen fixation.

With the exception of "green manures," which make inorganic minerals more accessible for plant growth, manuring does not, in itself, generate nutrients (57). The conversion of forage to manure (e.g., by cattle) results in a net loss of organic matter and minerals. For example, results from a study on a Rwandan farm show that 3.8 tons of dry forage containing 370 kg of minerals produces approximately 2 tons of dry animal manure containing only 300 kg of minerals (67). On the other hand, manuring is an important means of transferring nutrients from pastureland to cropland, or returning some of the nutrients that animals harvest to the field. The benefits are largely attributable to the increase in soil organic matter and include (5):

- improved soil macro-structure;
- increased water-holding capacity of the soil, particularly the topsoil;
- improved infiltration and erosion control;
- prevention of soil hardening;
- improved soil cation exchange capacity, of particular importance for the sandy soils of west and southern Africa;
- increased supply of slowly releasing inorganic nutrients;
- prevention of phosphate fixation by iron and aluminum oxides; and
- development of a favorable environment for microbial activity in the soil.

Despite the relatively high number of animals per capita in Africa, the use of animal manure is not great. In arid areas where cattle husbandry is strictly nomadic, collecting dung is impractical and it would be uneconomical to transport this material to crop growing areas. Moreover, the wisdom of exporting nutrients from the low-fertility rangelands is highly questionable. Under semi-nomadic husbandry practices, however, an association can exist between herder and farmer, whereby cattle are allowed to graze crop stubble in exchange for their manure. This system has been shown to be more economical than if the farmers owned and managed the livestock (9). The practice can help maintain soil fertility, but is insufficient to allow sustained cultivation without additional nutrient input.

Even on farms where crops and animals are produced, manuring sometimes is not common presumably because it is not economically viable (30,35). Manure requirements for crops are high (e.g., from 5 to 20 tons of fresh manure per hectare) (25), and managing manure is labor-intensive and requires transport and tools. Therefore, manuring has more potential for use in vegetable plots and home gardens than in the larger, more distant fields used to grow cereals and other staples. The primary reasons for keeping animals are for security, traction, meat, or milk (see ch. 11), but manure can be a byproduct that makes the adoption of animals more attractive.

The most effective means of collecting animal manure undoubtedly is by keeping animals stabled day and night. This yields about 8 times the animal's weight in manure per year. Alternatively, the animal can be stabled only at night, in which case it produces 3.5 times its weight in manure per year (17).

Inorganic Fertilizers

Phosphate rock is not used abundantly in African agriculture, but can be a locally important fertilizer, especially on acid soils. It can either be applied directly or processed before use. Several factors affect plants' ability to use phosphate rock. Some of these factors are related to the chemistry and mineralogy of the rock, others to the properties of the soil, or to the physiological makeup of the crop. The mineral can be used in several ways, in increasing order of the degree of processing required:

1. direct application of finely ground rock;
2. development of granular forms of the rock to improve handling characteristics;
3. combination of the finely ground rock with other materials such as elemental sulfur, manures, and compost; and
4. production of partially acidulated phosphate rock to improve solubility. The most processed forms involve substantial cost and energy to manufacture.

Photo credit: Banoun & Caracciolo/U.N. Food and Agriculture Organization

Farmers applying inorganic fertilizer to a yam field in Nigeria.

The most highly processed forms of fertilizer, commercial fertilizers, are sometimes called conventional, chemical, petrochemical, or fossil fuel-based fertilizers. In addition to minerals found in rocks, commercial fertilizers use compounds present in fossil fuels as their raw materials. Fossil fuels are also used to supply the energy necessary to process the materials. Therefore, commercial fertilizers, especially those high in nitrogen, are comparatively expensive to produce. However, they can be an extremely convenient method of supplying minerals in forms very accessible for plant growth.

Current commercial fertilizer use in Sub-Saharan Africa is the lowest in the world. The region contains approximately 7 percent of world population, but uses only 0.9 percent of world commercial fertilizer supplies. The average consumption rate is about 6.4 kg nutrients/

ha/year; by comparison, in 1983 the average consumption rate was 85 kg/ha/yr for the world, 33 kg/ha/yr for Latin America, and 81 kg/ha/yr for Asia (25). National consumption rates vary considerably in Africa, however. Three countries—Nigeria, Zambia, and Zimbabwe—account for 50 percent of the total consumption in Sub-Saharan Africa. Much of this fertilizer is used on cash crops rather than on local food crops. With the exception of a few countries such as Nigeria and Niger, about one-half to two-thirds of the fertilizer is used on crops grown primarily for sale.

All of the mineral resources needed to manufacture commercial fertilizers occur in varying amounts in Sub-Saharan Africa. Data suggest that adequate quantities of phosphate and nitrogen raw materials may exist, but potash and sulfur resources are inadequate to meet the region's needs (82). It is not known if exploitation of these resources is technically and economically feasible under present conditions. The advantages of using indigenous resources, even in times of adequate world supply, include supply security, foreign exchange savings, reduced transportation cost, and employment generation.

Since phosphorus deficiency has been identified as a major soil constraint in Africa, national and international research organizations have shown interest in developing the deposits of phosphate rock that exist in 26 Sub-Saharan African countries (51). However, only two countries, Zimbabwe and Senegal, produce phosphate fertilizers in any significant quantity, and farmer use remains low despite efforts such as those in Senegal, Mali, Burkina Faso, and Niger to provide farmers with phosphate rock at prices lower than imported fertilizer (82). Also, excluding deposits in eastern Senegal, Mali, and Niger, most of Africa's known deposits are "unreactive"—their natural form is not conducive to plant uptake and therefore requires considerable processing. And in the dry, dusty, and windy environments of the Sahel, application of finely ground phosphate rock—the most effective form—is too labor-intensive.

The full benefits of phosphate rock are realized for several years after application. This may mean that return to investment on the labor and capital costs is more favorable than initial calculations might suggest (53). However, farmers may find it difficult to capture these residual benefits unless they can develop appropriate crop rotations. Problems associated with farmer unwillingness to make such investments without secure land tenure can further undermine adoption of this practice (82).

Potential for Improving Soil Fertility

Organic Fertilizers

Organic fertilizers can play an important role in ensuring that soil fertility is adequate for producing stable yields of African crops. One approach is BNF, which can be promoted through wider use of legumes in intercrops and rotations, agroforestry systems, and in fodder pastures, and greater use of *Azolla* in rice production. Even if a crop is not able to fix nitrogen, nutrient loss can be reduced by as much as 50 percent if crop residues are left in place or returned to the soil (82).

Manures can increase yields substantially, but economic analyses have rarely been conducted. These analyses would be complicated because of the indirect effects of manuring on improving soil quality (29). Manuring can be expected to become more widespread in the future as animals become more fully integrated into farming systems.

The decomposition of plant and animal wastes in soil has other important benefits: gradual release of nutrients and increased water retention. Furthermore, soil with adequate organic matter can take full advantage of phosphate rock and more highly processed chemical fertilizers, increasing yields beyond those obtained by adding organic matter or commercial fertilizer alone (table 7-4; figure 7-4).

Inorganic Fertilizers

The known reserves of phosphate rock that are economically accessible with current tech-

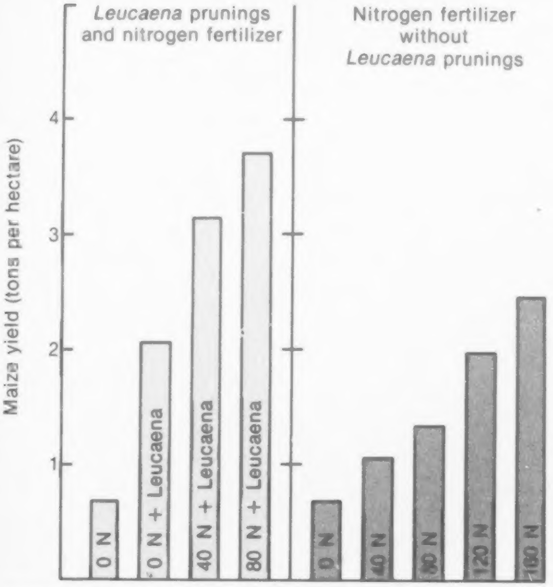
Table 7-4.—Effect of Manure and Commercial Fertilizer on Sorghum Yield at Saria, Burkina Faso

Treatment	Sorghum yield (kg/ha)[a]	
	Without nitrogen	With 60 kg/ha nitrogen
Without manure	1,831	2,796
With 10 tons of manure per hectare	2,409	3,591

[a] Kg/ha = kilogram per hectare.

SOURCE: Christian Pieri, "Food Crop Fertilization and Soil Fertility: The IRAT Experience," *Appropriate Technologies for Farmers in Semi-Arid West Africa*, Herbert Ohm and Joseph Nagy (eds.) (West Lafayette, IN: Purdue University, 1985), table 11, p. 89.

Figure 7-4.—Increased Maize Yields in an Alley Cropping System Using Prunings From *Leucaena leucocephala*, a Nitrogen-Fixing Tree, and Varying Rates of Nitrogen Fertilization



SOURCE: International Institute of Tropical Agriculture, *IITA Research Highlights 1984* (Ibadan, Nigeria: IITA, 1985).

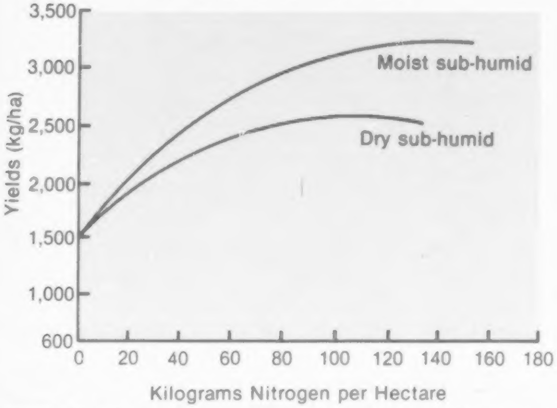
nology are small in most sub-Saharan countries. However, these reserves are large enough to meet phosphate fertilizer requirements of some countries for decades. Significant yield increases are possible even using unprocessed phosphate rock. For example, the application of 30 kg P_2O_5/ha of indigenous rock in a trial in Niger almost doubled the yield of millet (from 300 kg/ha to almost 600 kg/ha). Similar results have been obtained in many coastal West African countries and in Kenya (2).

Small-sized granulation of the fine rock powders (minigranules) using binders may be an effective way of avoiding the dust problems associated with using the fine powder. The adoption of this technology will depend on the cost of pelletizing.

Reducing the amount of acid needed to digest the rocks fully (partial versus full acidulation) results in a product that is only slightly less reactive than the fully digested material. In several field trials in various parts of tropical Africa (2), partially acidulated products made from normally unreactive phosphate rocks produced similar yields as the fully acidulated superphosphate. Because savings exist in acid consumption during the production, products are expected to be cheaper than imported commercial fertilizers.

Little question exists that Africa will have to increase its use of commercial fertilizers if it is to decrease the gap between food demand and supply. The ability of commercial fertilizers to increase yields is undeniable (figure 7-5), but two major concerns arise regarding their use in Africa. First, few economic analyses of fertilizer use under African conditions have been done, and those studies that do exist mostly reflect the ideal conditions found at agricultural research stations (e.g., deep plowing, complete weed control) (49). The high cost of commercial fertilizers and the variability of response under on-farm conditions, especially rainfed agriculture, argue for extreme caution when extending this technology to farmers with little margin for failure. Second, some studies of the long-term effects of continuous use of commercial fertilizer on the soil suggest that it can

Figure 7-5.—Response of Maize to Nitrogen in Different Climatic Zones



SOURCE: Paul Vlek, A. Mokwunye, and M. Mudahar, "Soil Fertility Maintenance in Sub-Saharan Africa," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).

actually depress yields unless large amounts of organic material, such as animal manure, also are added to the soil. Trials in Burkina Faso showed steadily declining sorghum yields over 18 years due to soil acidification, potassium deficiencies, and aluminum toxicity (63). These findings tend to reinforce the need to view inorganic fertilizers as supplements to, and not replacements for, organic fertilizer.

Problems and Solutions

Low soil fertility is one of the principal obstacles to sustained crop production in Africa. Alleviating this constraint will require a concerted research and development effort. Current approaches to soil research are largely fragmentary and a coordinated effort is needed that addresses the problems and options of ensuring soil fertility maintenance in different agroecological zones.

Increasing the use of organic fertilizers should be an integral part of this strategy. Optimizing the use of organic fertilizers is particularly important for those resource-poor farmers in isolated regions, where input delivery systems are problematic. Considerable opportunity exists to increase organic fertilizers use by expanding use of legumes in agroforestry and intercropping systems, and by better integrating crops and livestock in African farming systems (see chs. 8 and 10, respectively). Improving benefits of biological nitrogen fixation in African farming systems will require increased support for training African professionals and technicians, and increased research relevant to Africa, for example, on legumes in multiple-cropping systems. Such research and training could be supported through the funding of an international BNF Resource Center (18).

Increased use of inorganic fertilizer also will be essential to meet Africa's future soil fertility needs. The fertilizer sector in Africa is in its infancy. One constraint is the lack of consistent, long-term government and donor policies regarding fertilizer use. African governments are either ill-prepared or unwilling to create such policies. Donors sometimes exacerbate the situation. For example, until 1983, the policy in Rwanda was to deemphasize fertilizer use. FAO and the European Economic Community helped convince the government that fertilizers were an essential ingredient for the future and Rwanda proclaimed 1985 the year of the fertilizers. However, U.S. AID and its German counterpart, GTZ, adhered to the earlier policy that gave a low priority to fertilizer use. In the meantime, Rwanda still lacks a comprehensive, long-term plan for the development of the fertilizer sector (82).

Most countries in Sub-Saharan Africa are facing fertilizer supply and demand problems (56, 90). Frequently, fertilizer is not available at the right time and place, and many countries are unable to meet even low fertilizer demands or reduce supply fluctuations. Factors contributing to low fertilizer demand include:

- low crop response;
- lack of knowledge on fertilizer practices;
- high fertilizer cost and lack of cash or credit;
- high risk of losing money as a result of the variability in crop response and prices;
- low crop prices; and
- lack of complementary farm inputs such as fertilizer-responsive crop varieties, water, and insecticides.

Successful fertilizer programs require soil fertility maps, geologic research on important mineral deposits, establishment of soil testing laboratories, formulation of soil- and crop-specific fertilizer recommendations, and initiation of well-designed fertilizer demonstrations under farmers' field conditions. At present, fertilizer recommendations for specific agroclimatic conditions, crops, farming practices, and soil conditions generally do not exist. Current government recommendations not only may be inappropriate but actually may be counterproductive.

Accomplishing these tasks would require a major commitment of resources. According to the International Fertilizer Development Center, an estimated 1,600 people per year are needed over the next 20 years to work in sub-Saharan Africa's fertilizer sector, including fertilizer production, marketing, and use (82).

Fertilizer research programs are likely to be more effective if they adopt a farming systems approach that emphasizes the economic feasibility of fertilizer use and includes on-farm trials. Effort should be directed at reducing variability in crop's response to fertilizers, but economic analyses should not fail to include the risk associated with fertilizer use. Also, analyses should be realistic about portraying field—not ideal—conditions. When farmers use fertilizers on their own fields, their financial returns typically are only one-half to two-thirds those gained under experimental conditions. In addition, farmers generally pay more for fertilizers than the official, government-sanctioned, price (49).

In situations where economic analysis supports fertilizer use, credit may be needed. If so, providing credit at a market rate of interest should help reduce inefficient fertilizer use. As an alternate strategy, fertilizer sales on credit could be linked with crop marketing, that is, farmers could repay the fertilizer loan after harvest from receipts of crop sales. This idea has been used successfully by cooperatives in several Asian countries. Private traders, who are also fertilizer dealers, often practice such a sales strategy (82).

SMALL-SCALE IRRIGATION[3]

Summary

The Sahelian droughts of the early 1970s and mid-1980s that affected most of the continent have dramatically illustrated Africa's susceptibility to erratic and inadequate water supply. At least half of Sub-Saharan Africa, excluding the Sahara Desert, is arid or semi-arid, and untimely supply of water for crops and animals adversely affects much of the remaining area. Against this backdrop, the allure of irrigation needs no explanation.

FAO estimates that irrigated cultivation is practiced on 4 percent of the land classified as arable and under permanent cultivation in tropical Africa (77). An estimated 43 to 50 percent of this area could be considered low-resource agriculture (77,79). In much of the small area where large irrigation schemes are feasible, they already exist. Therefore, the remaining opportunities for irrigation in Africa are primarily for small-scale approaches (84).

Each of the four small-scale irrigation practices described here operates within a particular socio-ecological niche (table 7-5). They may be quite beneficial under specific, often geographically limited conditions, but unfeasible or economically unattractive elsewhere. This is especially true of channeled, poldered, and non-mechanized water-lifting practices,

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[3] This material is based primarily on the OTA contractor report prepared by Alfred S. Waldstein, Associates in Rural Development, Burlington, VT (app. A).

Table 7-5.—Estimates of the Distribution of Small-Scale Irrigation Technologies in Africa

Type of system/location	Number of users	Area (in hectares)	Number of schemes
Channeled systems			
East African Highlands:			
Tanzania	NK[a]	117,000	NK
Kenya	NK	900	NK
Malawi	NK	5,000	NK
Madagascar Highlands	NK	700,000	NK
Middle & Lower Shabelle River (Somalia)	NK	16,000	NK
Poldered systems			
Upper Guinea coastal lowlands	700,000-900,000	NK	NK
South-east Lake Chad	NK	4,000	NK
Water-lifting systems			
Sahel:			
Burkina Faso	NK	6,200	600 +
Chad	NK	2,500	NK
Niger	NK	14,500	NK
Coastal west Africa			
Gambia	NK	10,000	NK
Southern Africa			
Zimbabwe	NK	400	NK
Mechanized water-pumping systems			
Zimbabwe	7,000	4,700	67
Nigeria	NK	800,000	NK
Niger	NK	36,500	500 +
Sudan	NK	140,000	NK
Chad	NK	8,000	NK

[a] NK = not known.

SOURCES: Compiled from a number of references in: A.S. Waldstein, "Low-Resource, Small-Scale Irrigation in Africa," contractor report to the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987) and A.S. Waldstein, personal communication, revisions to OTA contractor report, 1987.

and less so of mechanized water pumping systems. To determine which technology to implement under given circumstances, planners and decisionmakers must take the following into account:

- local ecology, hydrology, geology, and topography;
- implementation and maintenance costs;
- access to investment credits;
- national pricing, import/export, and foreign exchange policies;
- access to material, services, and inputs required to support the technology;
- proximity and access to markets;
- availability of and competition for labor; and
- local systems of land and water rights.

Small-scale irrigation could become an important component of a strategy for intensifying agricultural production throughout much of Africa. Its benefits—increasing and stabilizing cropland productivity—are often sustainable for two reasons. First, costs to develop the systems generally are low, being more labor- than capital-intensive. Second, the initiative to develop and maintain small-scale irrigation rests with the users, so management grows out of the users' social system rather than being imposed on it. Also, small-scale irrigation projects can avoid many of the health, environmental, and social problems associated with large-scale projects (62,66,77).

Development assistance can support small-scale irrigation through technical and socioeconomic research; training extensionists in management options and supporting their involvement in farming systems research; and fostering national and local credit programs for generating investment capital.

Small-scale irrigation, for the purposes of this report, is characterized by:

- systems managed as an integral unit by an institution created by, composed of, and led by users;
- users make the decisions regarding the role irrigation will play in their agricultural production strategies and farming systems;
- usually the cost of development and operation of the system is low and covered, in large part, by user labor and inputs; capital costs, in particular, are low and normally can be assumed by users; and
- users generally develop the technical skills to design, build, and operate the system through a continuous iterative process.

Gravity Diversion Systems

Channeled Systems

Water is diverted into this type of irrigation system, from streams, springs, and lakes, by a network of channels. Individual fields are divided from each other and separated from the channels by low bunds. Fields are usually flooded by breaking the bund at one point to allow water to enter. The break is closed off with mud, wattle, or a sack filled with sediment at the end of watering. The water is being used, in effect, to extend the rainy season and reduce the risks of rain-fed agriculture. Irrigation, plus rainfall, typically allows more than one harvest per year. The system can be designed, built, operated, and maintained primarily with local labor, and the users can meet most institutional needs. Initial costs sometimes are not low, but operating costs typically are.

The main locations using gravity diversion channeled irrigation systems are the highlands of East Africa and Madagascar, and the Middle and Lower Shabeelle Valley in Somalia. In Somalia, about half the land on the Middle and Lower Shabeelle is irrigated by gravity fed channels. The technique is used in Tanzania on an estimated 117,000 ha, or 82 percent of all irrigated land (55), and in Madagascar on 70 percent of the 1 million ha under irrigation (28). Gravity-fed channeled irrigation, by contrast, covers no more than 4 percent, 800 to 900 ha, of irrigated land in Kenya (31).

Many of these systems, such as those along the Shabeelle River in Somalia, have been in existence at least since colonial times. They have fallen into disuse due to problems with water-borne disease, labor recruitment, migratory wage labor, land tenure problems, and unfavorable systems of justice and administration (14,31,60). The most important constraint to wider use, however, is that although investment requirements are small, returns on investment also are small. These systems do not include storage, so water is only available seasonally.

Poldered Systems

Poldered systems are made up of an intersecting network of channels built on low-lying swampy plains to help conduct the inflow and outflow of water. The purpose of poldered systems of the Upper Guinea coast is to drain water to the sea in the rainy season and conduct saltwater inland, especially at high tides, during the dry season. Sea water is permitted to enter the polders in the dry season, after harvest, to maintain soil plasticity. Salts are leached from the soil by flooding the channels with fresh water at the beginning of the next rainy season. After the soil has been de-salted, the polders are closed and crops planted. Farmers use the residual moisture from the river water in conjunction with rainfall to produce their crops (42,43,44).

The poldered systems around Lake Chad are managed differently. They are created by building dikes to trap water between two islands in the lake. Water infiltrates the lake bottom and people plant in the exposed moist, heavy clays. Later, they open the dike to flood the land again and wash out accumulated salt (3). As with the channeled systems, the poldered systems are technically and institutionally within the control of the users. The cost of technology is low in cash terms, although labor costs can be high. Most existing poldered systems support subsistence production.

Just as with channeled systems, poldered systems date back to or even precede the colonial era. However, the Lake Chad polders have fallen out of production in recent years. A succession of drought years has caused a major recession of the lake's shores and empoldered areas now may be many kilometers from the water's edge. In addition, many polders in Guinea-Bissau were destroyed during the war for independence, which ended in 1974.

Polder technology is feasible only in well-watered, lowlands with rich soils. Because of their particular ecological requirements, little extension of these systems is possible. Rain often is critical: in coastal areas, lack of rain means that saltwater will not be flushed downstream and salts accumulate; and in the Lake Chad region, without rain the lake level cannot rise enough to flood the polders. Polder technology is used mainly for subsistence. However, some production is on a large enough scale to produce substantial surpluses for market. Since the polders are virtually surrounded by water, these areas tend to have relatively easy water access to markets in areas where market roads may be lacking.

Water-Lifting and Pumping Systems

Water-Lifting Systems

Water-lifting technologies available to resource-poor farmers and herders include calabashes, buckets and pails, tin cans of various sizes, paddles, waterwheels and shaddoufs (a traditional water-lifting device), and handpumps. All of these technologies depend on a relatively high water table since they use human or animal energy to lift water from hand-dug wells into the main channel of the irrigation system. As a general rule, because of the physical limits of human drawing power, one well can irrigate only 0.25 to 0.5 hectares this way. The scale of operations made possible by a single well is so small that this irrigation technology needs practically no institutional support.

Photo credit: George Honadle

Water pumped by hand, by small engines, or by windmills provides irrigation for vegetable gardens such as this one in Botswana.

These water-lifting systems are usually operated seasonally to supplement rain-fed food production or livestock herding. Also, they may operate during the dry season to produce high-value crops for market, such as vegetables. However, sometimes small water-lifting systems are operated year-round for additional uses. In Chad, for example, in addition to the usual dry season crop of vegetables, maize germinates with help from a water-lifting system, then matures under rainfed conditions. Thus, water-lifting systems make possible a second cropping season and effectively extend the rainy season for staple food crops (83).

Irrigation technologies that rely on human or animal power to feed water into the system are scattered across Africa, concentrated in low-lying areas where the water table is relatively close to the surface. They are especially common across the Sahel from Senegal to Sudan. In addition, a number of systems exist in northern Togo, northern Ghana, and throughout Burkina Faso. These systems are fed from village barrages (small dams) that store rainwater runoff. Water-lifting systems are relatively scarce in eastern and southern Africa where the water table generally is deeper and soils rockier and more difficult to penetrate with wells.

Although the technology is not new, most of the water-lifting systems in Africa are relatively recent. They have developed rapidly in the Sahel since the onset of the series of drought years starting in the late 1960s. Systems in southern Mauritania date from the mid-1970s, and use of the shaddouf water-lifting devices in the Lake Chad basin dates from the same period. These recent systems are being used by small, scattered groups. Herders in Chad from the north and east came to the shores of Lake Chad to practice shaddouf cultivation when they lost their herds. People in northern Burkina Faso and southern Mali are using water-lifting technologies to grow potatoes to compensate for the drop in millet and sorghum production caused by recent dry conditions. Rural farm families using these systems tend to be less well-off than average (with the exception of the Niayes area in Senegal and some parts of Niger). Better-off families either had resources to invest in pumping or managed to preserve their livestock.

Water-lifting technologies can be profitable where markets are nearby because of their low costs for construction, operation, and maintenance. Recent advances in developing inexpensive and reliable handpumps, however, are particularly encouraging (box 7-1). Even under these conditions, though, handpumps are often used only in the off-season to produce a small crop or during droughts. People may try to expand their operation by investing in pumping as market and production opportunities develop. Therefore, water-lifting technology can be considered a transitional step toward more intensified, highly mechanized, agriculture using handpumps.

Mechanized Water Pumping

Mechanized water pumping makes it possible to draw relatively large quantities of water from wells or rivers. Pumping schemes are operated by a wide variety of users, such as private entrepreneurs, cooperatives, and village organizations. The cost of buying, operating, and servicing the pumps makes this practice more expensive than other low-cost irrigation technology. Typically, only a minority of the local population benefits from pumping schemes because of the rigorous implementation requirements (e.g., initial investment costs). However, in some cases, whole villages are involved. Despite the expense, pumps are capable of generating significant returns for their users.

Mechanized pumps, because of fuel costs, usually are operated only during the dry season to grow high-value crops for market. Also, mechanized water pumping systems tend to be concentrated within convenient transport distance of large markets. More than other low-technology irrigation, they need support services, such as trained mechanics, to stay in operation.

Water pumping using small diesel engines to power pumps is the most widespread and rapidly expanding low-resource technology used in African irrigation, and examples are scattered Africa-wide (84). Their presence is a function of three factors: availability of water, access to credit for the initial cash investment, and access to lucrative markets.

Water pumping systems are common along Africa's large rivers; for example, at least 400 such systems exist in Senegal, Mauritania, and Mali along the Senegal River. People also pump water from lakes and holding ponds. The International Irrigation Management Institute estimates that private pumping schemes in Sudan provide water to 134,000 ha (28). These schemes in general are so dispersed or isolated that it has been impossible to survey them, but thousands of pumping systems, no doubt, exist throughout tropical Africa.

Constraints to their wider use include the expense of purchasing and operating pumps, lack

Box 7-1.—Handpumps

Manual pumps have long been recognized as one of the most promising hardware options for village-level water supplies in most rural areas, but a variety of obstacles have hindered reliable handpump operation in many developing countries. Many imported models were simply too costly; spare parts were expensive and hard to get; breakdowns were frequent; and maintenance and repair systems—where available—were overly centralized and burdensome. As recently as a decade ago, the United Nations Children's Fund (UNICEF) reported that at any given time 70 to 80 percent of handpumps installed in India were nonfunctional. The performance records for handpump projects in Africa were equally disappointing.

However, handpumps do show promise. Through a network of field-testing activities in some 17 developing countries supported by a collaborative United Nations Development Program/World Bank project, a half-dozen countries across three continents are now producing handpumps locally. The "handpumps project" also has provided detailed information for a comprehensive manual which will aid in handpump selection, design, and use in countries throughout the developing world.

From India to Malawi

Beginning in the late 1970s, UNICEF supported local production of an innovative design called the "Mark II" which set new standards of reliability and cost-effectiveness at the village level. At least 150 million people in India are presently served with safe water supplies using almost half a million Mark II pumps.

Soon, experiences and lessons learned in India were carried to a local production programme in Malawi under government and project sponsorship. The new "Maldev" design spread rapidly across the country. However, like the Mark II, the Maldev pumphead relied on fitted metal bearings which suffered rapid deterioration and were difficult to properly replace at the village level.

From Malawi to Kenya

A technical team in Nairobi, working with local manufacturers and the DuPont company, produced a modified Maldev design featuring injection molded plastic bearings. Working through other design problems with the Malawi pump, the Kenyan team began field-testing the "Afridev" pumphead, proving that the plastic bearing concept could be cheaper to maintain and easier to repair at the village level.

The Kenya Water for Health Organization was enlisted to train rural women in proper use and maintenance of the prototype pumps. By the end of 1986, the first 200 Afridev pumps were rolling off the production lines.

According to World Bank regional project officer, David Grey, the Afridev system represents a major conceptual breakthrough because:

> . . . it's designed to exploit the benefits of modern materials and technologies, especially plastics. It is suitable for local manufacture in developing countries. It's easily maintained using minimal skill and few tools. It features a universal small diameter, long stroke cylinder for all well depths, simplifying spare parts requirements and minimizing stress forces.

The total cost of the complete pump assembly is no more than US$400, and most of the below ground components for the system are made of standard PVC plastic which is readily available in Kenya and other east African countries. The cost of locally-produced replacement bearings is only US$4 for a complete set.

Back to Malawi—and Beyond

Through the collaborative network set up by the project, the improvements featured in the Afridev system were soon being carried back to Malawi. There they were integrated into the local manufacturing processes and taken to the village level where women, once again, are becoming the central personnel for pump maintenance and repair. The Afridev design is also being adopted in Ethiopia and Tanzania where project officials feel confident that local production and use can begin in 1988.

SOURCE: Anonymous, "Handpumps Across the South," *Cooperation South*, No. 2, 1987, pp. 3, 17.

of credit, shortage of spare parts, and local incapacity to repair equipment. Appropriate engineering is also a major shortcoming with many pumping schemes. The canal layout of many schemes is not well planned, and consequently, they distribute water inefficiently (84).

Potential

FAO estimates that 5.3 million ha, or 4 percent of the land classified as arable and under permanent cultivation, are under irrigated cultivation in tropical Africa (77). From 43 to 50 percent of this could be considered low-resource agriculture (77,79) (table 7-6).

The topography of Africa is not conducive to large-scale irrigation, in contrast to Asia, for example, which had at least 56 percent of the world's irrigated cropland in 1981 (88). Other than the interior delta of the Niger River, no large alluvial plains exist in Africa with multi-season water supplies and soils with adequate clay content (84). Systems already exist in much of the limited area where large irrigation schemes are feasible. Therefore, the remaining opportunities for irrigation development in Africa are primarily of smaller scale (84).

Small-scale irrigation can contribute to food security in a variety of ways:

- increasing crop or livestock production;
- reducing risk of crop/animal failure by increasing dependability of water supply;
- enabling the production of a second crop by lengthening the growing season; and
- increasing income for the above reasons, including production of new crops, particularly vegetables.

Small-scale irrigation projects commonly are less expensive than larger schemes (71,77), and may be less susceptible to health problems caused by disease-carrying organisms that flourish in standing water. Management needs for small-scale projects usually are easier to satisfy. Research organizations, development agencies, host governments, and users generally agree that these technologies have great potential under the right ecological and demographic conditions (84).

FAO estimates expansion of irrigation through the year 2010 could average some 50,000 ha/yr. Rehabilitation of existing schemes would add 25,000 ha/yr and expansion of traditional and small-scale irrigation could reach 150,000 ha/yr (49,54,77).

Among the low-cost irrigation technologies, diesel pumping has the greatest technical potential for increasing productivity and it can be used under the widest environmental conditions. However, it is also the most expensive and the most dependent on outside resources.

Table 7-6.—Distribution of Modern and Traditional Irrigation in Sub-Sahara Africa

	Modern and large- & medium-scale	Small-scale and traditional	Total
Regions*	Million hectares		
Sudano-Sahelian Africa	1,917	340	2,257
Humid and Sub-humid West Africa	144	1,190	1,334
Humid Central Africa	18	60	78
Sub-humid & Mountainous East Africa	282	910	1,192
Sub-humid & Semi-arid Southern Africa	308	150	458
Total	2,669	2,650	5,319

*Countries included in FAO regions.

1. Sudano-Sahelian Africa:
   Burkina Faso, Cape Verde, Chad, Djibouti, The Gambia, Mali, Mauritania, Niger, Senegal, Somalia, Sudan.
2. Humid & Sub-humid West Africa:
   Benin, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Nigeria, Sierra Leone, Togo.
3. Humid Central Africa:
   Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon, Sao Tome & Principe, Zaire.
4. Sub-humid & Mountainous East Africa:
   Burundi, Comoros, Ethiopia, Kenya, Madagascar, Mauritius, Reunion, Rwanda, Seychelles, Uganda.
5. Sub-humid & Semi-arid Southern Africa:
   Angola, Botswana, Lesotho, Malawi, Mozambique, Nambia, Swaziland, Tanzania, Zambia, Zimbabwe.

SOURCE: U.N. Food and Agriculture Organization (FAO), *African Agriculture: The Next 25 Years, Annex IV, Irrigation and Water Control*, FAO, Rome, 1986, p. 16.

The less expensive technologies—channeled, poldered, and water-lifting systems—have less potential for expansion, primarily because of environmental considerations, but all could be improved by technical assistance. Furthermore, these approaches can serve as first steps toward long-term intensification of food production. Access to markets for all these technologies would be an important incentive for users to incur the cash and labor costs of intensifying production (84).

Small-scale irrigation could make a particularly important contribution in Africa because it decreases farmer vulnerability to drought-induced crop failure by ensuring a more reliable water supply. However, increased costs and reliability of outside inputs have a strong bearing in defining the economic advantages of improved water supply schemes. Irrigation generally requires greater inputs of time, effort, and capital than rain-fed agriculture or livestock herding systems normally practiced in tropical Africa. Shortage of labor is cited as a major constraint to irrigation development in Africa, except in more densely populated areas where labor supply is readily available (84). Evaluating these sorts of considerations, as well as examining a range of water supply options that best accommodate local conditions, should precede efforts to extend irrigation technology.

Caution is also needed when introducing small-scale irrigation to minimize problems of social inequities that irrigation technologies can create (4). Even under the best of conditions, low-resource irrigation will be possible only at particular sites that represent a relatively small part of the cultivable land. Pressures, tensions, and competition may develop around these sites for access to land. Avoiding such conflicts may require that local and national governments address complex and difficult land tenure issues. The impact and contributions to women's economic activities should also be specifically considered.

Several factors have appeared in recent years to create a promising environment for the expansion of low-resource irrigation:

- African governments and development agencies are investing in it;
- the policy climate is becoming more favorable;
- production crises in many countries are motivating donors, host governments, nongovernmental organizations (NGOs), and local citizens to expand irrigation;
- the increasing priority of food self-sufficiency encourages expansion;
- the international research community has recently launched a series of research programs on it; and
- it is well-suited to diffusion through NGOs (84).

Problems and Approaches

Much agreement exists among African governments and development agencies over the necessity of developing the irrigation sector. The nature of this development is less clear, however. Many African nations envision new, large-scale irrigation projects (62). Yet, these types of projects are proportionately more costly and are associated with numerous health, environmental, and social problems (62,77). A growing consensus places increased emphasis on small-scale projects. However, development assistance has not given high priority to these low-cost irrigation technologies (84). The chief reasons are their locale-specific applicability and requirements and the high cost of administering the project relative to the other project costs and economic benefits.

NGOs have an important role to play in the diffusion of low-resource irrigation technologies and can serve as intermediaries for AID and other large development agencies. NGOs are interested in, and well-suited to, assisting in the design and implementation of low-resource irrigation projects. Technical expertise varies greatly among NGOs, however, and many could benefit from technical assistance and support from the major development agencies (84).

The potential for expanding low-resource irrigation systems in Africa stems in large measure from the user's ability to retain independence and flexibility in operating them. Keeping the costs of developing, operating, and maintaining the systems low is essential in this regard. Further, expanding the potential of low-resource irrigation technologies should enable adaptations to meet a diversity of conditions. This may mean devoting as much attention to human resource development as to construction activities themselves.

Although small-scale irrigation is inexpensive locally, it will require significant levels of funding to reach its potential on a broad scale. The rough estimate provided by FAO for development of irrigation, large- and small-scale, calls for "US$475 million per year, or a total of $12 billion through year 2010, while incremental operating costs of irrigation would amount to an additional US$130 million" (77). Initiation of rural credit programs to underwrite individuals and groups to implement irrigation schemes is an important additional cost. Resources also will have to be allocated for research, training, extension, and policy support if small-scale irrigation is to have a large, beneficial impact.

Research

Some research is underway. For example, the Club du Sahel is launching a study to update its research of almost a decade ago on irrigation in the Sahel, and this will treat low-resource irrigation for the first time. Funding levels will determine how quickly these other important topics will be addressed:

- **Farming Systems Research**: To encourage wider adoption of low-resource irrigation technology, studies are needed of the role of irrigation in farming systems. Too often, studies are done on the management of irrigation systems, but not on the relation of this activity to other agricultural and non-farm activities. Such research could be a precondition for the design and implementation of an irrigation scheme. Farming system studies could catalog local resources, give a socioeconomic profile of beneficiaries, and evaluate their strategies for irrigation production in terms of risk aversion and long-term sustainability of production.
- **Technical**: More needs to be known about groundwater hydrology and surface water resources, including salinity levels and recharge rates. France's Office of Overseas Scientific and Technical Research (ORSTOM, by its French acronym) carried out a series of hydrological studies in the Chad portion of the Lake Chad basin in the late 1960s and early 1970s. The U.S. Coastal and Geodetic Survey performed similar research in the mid-1960s in the Nigerian part of the basin. But reliable hydrological data are unavailable for much of Africa. Extension of low-resource irrigation will have to be pursued cautiously in the absence of information on water supplies.

Training and Extension Services

Beyond the lack of knowledge and technical training in groundwater hydrology, the potential of irrigation technology suffers from a shortage of Africans trained in agricultural engineering. Villages, small groups, and private individuals without this expertise will find it difficult to obtain assistance in laying out efficient irrigation systems.

Training is also needed to help develop new or modified low-cost technologies to increase the performance of low-resource irrigation systems. For example, this could include ways to increase the efficiency of using the shaddouf, or low cost ways to reduce water infiltration in canals.

Researchers and funding also are needed to develop baseline data on the evolution of these technologies and to estimate their potential with increased confidence.

Most African extension services are poorly prepared to mobilize local groups to design, build, operate, and maintain low-resource irrigation schemes. Extension personnel, in general, have not been trained to see low-resource irrigation as a system with complex relations to other aspects of socioeconomic life. For example, extension staff commonly have narrow, technical backgrounds and may not be trained in community organization. Yet, in principle, extension services would be the key link between irrigation planners and organized groups of beneficiaries.

Policy Reform

Several areas of government policy, in particular, tax policy, land tenure issues, and decisions on private versus parastatal control, have major effects on irrigation. Issues for African governments include:

- Ensuring that inputs needed to foster irrigation and agricultural intensification are not so heavily taxed that they become unaffordable. Many African governments now are concluding that it is counterproductive to heavily tax imports that support food production. However, many need support in analyzing their tax policy for its effects on the extension of low-resource irrigation.
- Problems of land title and tenure can be serious constraints inhibiting the growth of small-scale irrigation (84). Without secure land tenure, farmers are unwilling to make necessary investments to develop and maintain irrigation systems. Changes in land tenure regimes, however, should account for those shifting cultivators and pastoralists dependent on traditional or communal systems of property rights. Similarly, provisions could be made to discourage land speculation that displaces poor farmers or herders in the wake of increasing land values resulting from irrigation projects.
- Improving the efficiency of many parastatal organizations or backing privatization efforts to transfer control from parastatal organizations to local organizations and other users. Many low-resource systems in Niger, Mali, Sudan, and elsewhere are excellent candidates for privatization (84).

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Chapter 8

Improved Cropping Practices

CONTENTS

Page
Intercropping 195
  Summary 195
  Various Types of Intercropping 196
  Benefits of Intercropping 196
  High Adoption Potential of Improvements 198
  Research Needs and Constraints for Intercropping 198
Agroforestry 200
  Summary 200
  The Role and Nature of Agroforestry 201
  Potential for Adoption 204
  Problems and Approaches 205
Chapter 8 References 208

Box

Box *Page*
8-1. Community Agroforestry in Somalia 207

Figure

Figure *Page*
8-1. Growing Thirteen Crop Species on and Between Raised Mounds in Nigeria 197

Tables

Table *Page*
8-1. Examples of Common Intercrops in the Agroecological Zones in Sub-Saharan Africa 196
8-2. Intercropping of Cereals in Africa 197
8-3. Possible Effects of Intercropping on Insect Pest Populations 199
8-4. Grain Yields Under the Crown of *Acacia albida* Compared to Grain Yields Outside the Crown 202

Chapter 8
Improved Cropping Practices

INTERCROPPING[1]

Summary

Intercropping, the growing of two or more crop species or varieties simultaneously in the same field, is the predominant form of agriculture throughout Africa. In West Africa, for example, 80 percent of the agricultural land is intercropped (12,47).

Intercropping is such a widespread practice among resource-poor farmers because of its numerous benefits. Intercropping:

- reduces risk of crop failure and improves production stability;
- increases yields per unit of land by more efficiently using natural resources;
- increases returns to labor and spreads labor requirements, thereby reducing labor bottlenecks;
- improves control of diseases, pests, and weeds; and
- reduces soil erosion and water runoff (7,13,15,35).

Because intercropping is a widespread, indigenous practice, it is unlike many unfamiliar technologies that are difficult to transfer from the research station to the farmer. Introduced improvements that build on this traditional practice are more easily accepted by farmers. However, despite its importance and prevalence among African farmers, intercropping has received relatively little research attention (12). This is partly because research objectives are more easily identifiable for single crops, because of a historical focus on non-food cash crops (e.g., cotton) which may be less suitable to intercropping, and partly because research decisions largely have been made by Western-trained scientists whose temperate-region experience has favored monocropping. Problems associated with monocropping, particularly in tropical agriculture, and a growing appreciation of the merits of intercropping, is leading to a reevaluation of conventional emphasis on monocrop research (4,40).

This reevaluation has led to a recent increase in intercropping research (4,13). This shift, although still small, has been motivated by the realization that in low-resource agriculture crop diversity is valuable, stability of production important, and optimum use of scarce resources necessary. The potential for meeting these objectives often is greater with intercropping than monocropping, thus arguing for increased funding and a continued commitment.

Development assistance can best support intercropping by: 1) not pressuring farmers to abandon the practice (e.g., currently agricultural credit and inputs may be supplied only for monocropping); 2) ensuring that additional research on agricultural technologies, such as fertilizers, is appropriate for intercrop situations; and 3) directing increased basic research to the practice itself (e.g., conducting research on ways to minimize competition between component crops). Intercropping could be improved significantly if it received the share of scientific research attention that it warrants based on its importance in African agriculture.

The most immediate gains can be achieved through integrating existing technology into intercrop systems, including new varieties, fertilizer, pest and disease management, animal traction, and even partial mechanization. Further gains may also be provided through research and technology developed specifically for intercrop systems, but these probably will evolve over a longer period.

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[1] The material on intercropping is based primarily on two OTA contractor reports prepared by David J. Andrews and Charles A. Francis (app A).

Various Types of Intercropping

Intercropping, as discussed in this chapter, is the growing of two or more crop species or varieties simultaneously in the same field. (This can include agroforestry—the use of trees in intercrops, which is discussed in the following section). Various types of intercropping systems exist:

- *Mixed intercropping*: a variety of crops are planted with no distinct row arrangement.
- *Row intercropping*: crops are planted in rows, either adjacent rows of different crops, or mixed within the row.
- *Strip cropping*: several rows of a crop are grown together forming a strip. Strips, each having a different crop or variety, are wide enough to permit independent cultivation, but close enough to interact agronomically.
- *Relay intercropping*: growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest. If crops are planted successively in the same year, but with no significant overlap in time, the system is called sequential cropping (7).

Food and export crops are grown as intercrops throughout all agroecological zones of Africa (table 8-1). National statistics rarely identify the production system, but studies clearly indicate that intercropping accounts for the majority of Africa's agricultural production (table 8-2).

In arid areas, two or three species commonly are mixed, but in wetter zones the systems become increasingly more diverse (47). The diversity of crops produced in the humid lowlands is illustrated in Zaire, where farmers sometimes grow 80 varieties of 30 different species. In one study, this included 27 varieties of banana and plantain and 22 varieties of yams and other root crops (13). In another example, Nigerian farmers designed a system of mounds which allowed them to plant crops with differing soil moisture requirements and thus greatly diversify their production (figure 8-1).

Table 8-1.—Examples of Common Intercrops in the Agroecological Zones in Sub-Saharan Africa

Zone	Crop mix
Arid and semiarid	millet/sorghum millet or sorghum/cowpea
Subhumid uplands	maize or sorghum/beans or cowpea rice/cassava
Humid lowlands	root crops/maize/food legumes/perennial crops
Tropical and subtropical highlands	maize or sorghum/beans or other food legumes bananas/coffee

SOURCES: David J. Andrews, "Intercropping in Low-Resource Agriculture in Africa," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987);
B.N. Okigbo and D.J. Greenland, "Intercropping Systems in Tropical Africa," *Multiple Cropping*, R.I. Papendick, P.A. Sanchez, and G.B. Triplett (eds.), American Society of Agronomy Publi. No 27 (Madison, WI: American Society of Agronomy, 1976), pp. 63-101;
D.R. Harris, "Traditional Systems of Plant Food Production and the Origins of Agriculture in West Africa," *Origins of African Plant Domestication*, J.R. Harlan, J.M.J. De Wet, and A.B.L. Stemler (eds.) (Mouton, The Hague, 1976);
Charles Francis (ed.), *Multiple Cropping Systems* (New York, NY: Macmillan Publishing Co., 1986);
K.G. Steiner, *Intercropping in Tropical Smallholder Agriculture with Special Reference to West Africa*, Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), Bonn, West Germany, 1982.

Benefits of Intercropping

Reduces Risk and Improves Production Stability

A principal reason why farmers have adopted intercropping is that it reduces risk, i.e., it increases the reliability or stability of production (1,16,30,36,41). Millet, for example, is less susceptible to drought than sorghum, with which it is often intercropped. The two crops also differ in their susceptibility to diseases, pests, and weeds. Thus, growing both increases the likelihood that there will be some harvest regardless of the damage of that season's pests or weather. If one crop dies, the remaining crop can help compensate for the loss by using some of the water and other resources that become available. Moreover, since different species usually are not planted at the same time, the farmer can compensate for the failure of the first crop by increasing the density of subsequent crops.

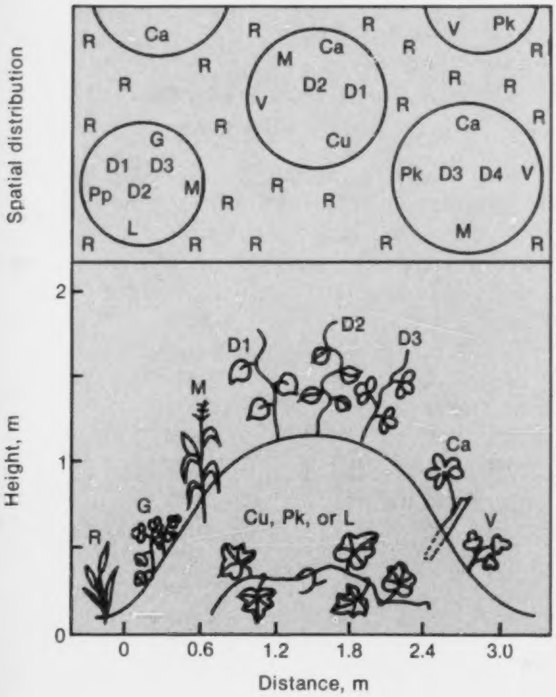
Table 8-2.—Intercropping of Cereals in Africa (percent intercropped)

Cereal	Ghana	Ivory Coast	Nigeria	Sierra Leone	Uganda
Maize	84	80	76	NA	84
Millet	87	81	90	NA	NA
Rice	29	75	58	91	NA
Sorghum	95	72	80	NA	46

NA = not available

SOURCES: David J. Andrews, "Intercropping in Low-Resource Agriculture in Africa," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).
M. Rao, "Cereals in Multiple Cropping," *Multiple Cropping Systems*, Charles Francis, (ed.) (New York, NY: Collier Macmillan, 1986).
D.S.C. Spencer, "Rice Production and Marketing in Sierre Leone," I.M. Ofori (ed.) *Factors of Agricultural Growth in West Africa*, Procedure of Internal Conference, Accra, Ghana, 1973.

Figure 8-1.—Growing Thirteen Crop Species on and Between Raised Mounds in Nigeria



Ca—Cassava
G—Groundnut
L—Lagenaria
Pp—Pigeon pea
V—Voandzeia
Cu—Melon
M—Maize
Pk—Pumpkin
R—Rice
D1—Dioscorea rotundata
D2—D. alata
D3—D. bulbifera
D4—D. cayenensis

SOURCE: B. Okigbo and C. Greenland, "Intercropping Systems in Tropical Agriculture," *Multiple Cropping*, R. Papendick, P. Sanchez, and G. Triplett (eds.), American Society of Agronomy Special Publication Number 27 (Madison, Wisconsin: American Society of Agronomy, 1976) pp. 63-101.

Increases Yields Per Unit of Land by More Efficiently Using Natural Resources

Intercropping also provides yield benefits over monocropping, usually measured as nutritional or economic gains, that can average 15 to 20 percent or in some cases more (51). One explanation for increased yields is that species and varieties differ to some extent in the resources that they need and how they obtain them (23). Differences among crops in their shoot and root geometry can allow mixtures of crops to exploit more of their environment than is possible in monocropping (48).

Competition between crops in the same field can have a negative impact on production but this problem is reduced when the selected plants differ in their life cycles and critical growth periods. For example, pearl millet and a traditional cowpea variety are often intercropped in the West African Sahel. Millet is planted with the first rains, and cowpeas planted only when the millet is well established. As a result, cowpeas offer little competition to the millet. The cowpeas are at first suppressed by the millet but this is of little consequence since cowpeas can only begin to flower after the rains end. By then, the millet is ready to harvest. The cowpeas continue to grow and flower after millet harvest so long as stored soil moisture is available. If rainfall is below average, cowpea pod yields will be low, but there will be hay for animals. In good rainfall years, the system has the flexibility to use the extra moisture efficiently with repeated harvests of cowpeas. Thus, the total growing season, whether short or long, is used more fully.

Intercrops containing legumes can help restore nitrogen to the soil. Unless the legume is earlier maturing than the cereal, there is no immediate transfer of fixed nitrogen from the legume to the cereal, but there is the beneficial residual effect of the legume on the next year's cereal crop. Legumes grown alone would also be able to add nitrogen to the soil, but the higher risk of increased damage by pests and disease can prohibit resource-poor farmers from raising them as monocrops.

Increases Returns to Labor and Spreads Labor Requirements, Thereby Reducing Labor Bottlenecks

Another important advantage of intercropping is that it reduces labor bottlenecks and gives a higher return on the labor invested (35). Labor requirements are spread out because planting, weeding, and harvesting schedules are different for each crop.

Furthermore, intercropping can reduce weed problems (6,13,20). In Nigeria, for example, a native legume has been intercropped with maize to suppress weeds. Since farmers in this part of Africa devote nearly half of their time to weeding and the amount of land a family can cultivate is normally controlled by how much family members can weed, intercropping can be very advantageous (3,21,35).

Improves Control of Diseases and Insects

Intercropped crops typically suffer less insect and disease loss than monocropped ones (5). Pest populations remain lower and they inflict less damage in intercropped systems (9, 43) (table 8-3). One reason for this is that the diverse crop environment provides shelter and necessary food sources for predators and parasites of the pest insects (42). In addition, pests and diseases damaging one crop may not be able to survive on other crops and intercropping decreases the number of plants on which they can live and makes those plants harder to find.

Reduces Erosion and Runoff

Intercrops can reduce water runoff and soil erosion where they provide more continuous coverage of the soil than occurs in monocropping. Also, the deeper layers of vegetation can reduce the impact of heavy rains and allow more water to infiltrate the soil (28,45). In one study, intercropping maize in cassava on a 15 percent slope reduced runoff and soil erosion relative to cassava alone by 38 percent (2). Wind-induced soil erosion and damage also can be reduced with intercrops. For example, on sandy soils in western Sudan sesame is planted with sorghum or millet when the cereals are large enough to shield the sesame seedlings from abrasion by windborne sand.

High Adoption Potential of Improvements

The long history and widespread acceptance of intercropping by resource-poor farmers makes it an excellent candidate for development assistance. Unlike many other technologies, the potential of intercropping can be realized without many of the typical constraints involved in transferring technology from the research station to the farmer. Perhaps the strongest argument for improving existing intercropping practices rather than trying to substitute monocrops is that all interventions—e.g., new varieties, fertilizer, pest and disease management, animal traction—have a good chance of success when they build on an already familiar base (17).

Research Needs and Constraints for Intercropping

Despite increased attention to intercropping over the last 20 years, it remains inadequately researched. Currently, only an estimated 10 percent of AID's research and extension efforts in agriculture involve intercropping (12). The knowledge base, research investment, and extension efforts for intercropping are insufficient given its prevalence and importance to food production as compared to monocropping.

The low level of attention and funding derives from the negative attitudes concerning in-

Table 8-3.—Possible Effects of Intercropping on Insect Pest Populations

Factor	Explanation	Example
Interference with host-seeking behavior:		
Camouflage	A host plant may be protected from insect pests by the physical presence of other overlapping plants.	Bean seedlings camouflaged by standing rice stubble helps limit damage from beanflies.
Crop background	Certain pests prefer a crop background of a particular color and/or texture.	Aphids, flea beetle, and *Pieris rapae* are more attracted to crops, (e.g., cabbage) with a background of bare soil than to plants with a weedy background.
Masking or dilution of attractant stimuli	Presence of nonhost plants can mask or dilute the attractant stimuli of host plants leading to a breakdown of orientation, feeding, and reproduction processes.	*Phyllotreta cruciferae* (flea beetle) can be diverted from collards to intercropped wild mustard.
Repellent chemical stimuli	Aromatic odors of certain plants can disrupt host-finding behavior.	Grass borders repel leafhoppers in beans.
Interference with population development and survival:		
Mechanical barriers	Companion crops can block the dispersal of pests across the intercrop. Restricted dispersal can also result from mixing resistant and susceptible cultivars of one crop.	
Lack of arrestant stimuli	The presence of different host and nonhost plants in a field may affect colonization by pests. If a pest descends on a nonhost it may leave the plot more quickly than if it descends on a host plant.	
Microclimatic influences	In an intercropping system favorable aspects of microclimate conditions are highly fractioned, therefore insects may experience difficulty in locating and remaining in suitable microhabitats. Shade derived from denser canopies may affect feeding of certain insects and/or increase relative humidity which may favor entomophagous fungi which feed on pests.	
Biotic influences	Crop mixtures may enhance natural enemy complexes leading to a greater abundance of natural enemies of pests in intercropping than in monocropping.	

SOURCE: Compiled by M. Altieri and M. Liebmann," Insect, Weed, and Plant Disease Management in Multiple Cropping Systems," *Multiple Cropping Systems*, Charles Francis (ed.) (New York, NY: Macmillan Publishing Co., 1986), p. 186. Data from: V. Hasse and J.A. Litsinger, "The Influence of Vegetational Diversity on Host Finding and Larval Survivorship of the Asian Corn Borer, *Ostrinia furnacalis*," IRRI Saturday Seminar, Entomology Department, International Rice Research Institute (IRRI), Los Banos, Philippines, 1981.

tercropping and the difficulty in researching it. Negative attitudes include the belief that intercropping is a primitive technology and the notion that intercropping can only absorb technical changes specifically researched for it. Such attitudes are inconsistent with research results however. A number of areas exist where intercropping can benefit from research designed for monocrops. For example, the responses of cereals to low levels of fertilizers are similar whether they are monocropped or intercropped. Row intercrops can also make use of advances in monocropping in such realms as new plant varieties, fertilizer and pesticide applications, and animal traction.

Research on intercropping can encounter unique difficulties. In some cases this is simply a function of having been neglected. Intercropping is a relatively new research area and, therefore, a smaller knowledge base exists. In other cases it is more a function of understanding the complexity of intercropping and the multiple interactions of crop species. Addressing this complexity is difficult because the majority of plant interactions probably takes place below ground. The complexity is further increased as specific types of intercrops are often adjusted to meet social needs (e.g., labor constraints), therefore, efforts to understand intercropping as an agricultural system must also draw on social science research.

As long as the majority of farms remain small, production per unit of land and labor will remain important and will favor the retention and improvement of intercropping. Specific intercrop combinations (though not the practice of intercropping itself) are relatively site-specific. Thus, improvements must necessarily come from research at the farm level. Areas for site-specific research include: determining optimum plant densities, crop combinations, and relative planting dates, and the best means to provide plant nutrition through use of organic and inorganic fertilizer.

Notwithstanding the need to emphasize local research, the following general research areas are also important to the improvement of intercropping.

- *Testing improved varieties for intercropping*: Although the best approach would be to breed varieties specifically for an intercrop situation, this is a long-term solution (12). For now, improvements can be achieved by testing and selecting for the best combinations from the existing range of varieties (52).
- *Incorporating animal traction with intercropping*: This is important for cultivation, weeding, transportation, and manure production. It will lead to an emphasis on row cropping. Other problems associated with the incorporation of animals into farming systems also will have to be resolved (see ch. 11).
- *Basic research*: Apart from on-farm research designed to give results for quick use by extension services, a need exists to understand more clearly how intercropping works—what is the nature of competition between species over the season, and what are the long-term environmental effects. An important research need is to understand competition for soil moisture and plant nutrients and resultant soil changes. Support could be given to institutions capable of using advanced research technologies such as neutron probes and isotope-labeled fertilizers needed to study below-ground interactions (7).

AGROFORESTRY[2]

Summary

Agroforestry is the term used for agricultural systems in which trees or shrubs are deliberately grown with crops and/or livestock. Although the term agroforestry has been coined only recently, agroforestry techniques have been practiced for generations. Indeed, trees and shrubs are an integral part of most traditional low-resource agricultural systems, and cleared treeless fields, such as those common in the temperate zones, are the exception rather than the rule in Africa (31). Agroforestry includes a wide range of practices:

- *Dispersed Field Tree Intercropping*: "Farm trees" are grown within and adjacent to crop fields. For example, in semi-arid areas a nitrogen-fixing tree, *Acacia albida*, can double yields of certain crops grown under its canopy and provide valuable browse for livestock. The tree reduces soil erosion and water loss from runoff and evapotranspiration (water loss from evaporation and crop transpiration) and allows more intensive use of the land (32).
- *Alley Cropping*: A newly developed technique in the humid lowlands allows crops to be planted in the narrow "alleys" between rows of nitrogen-fixing trees or shrubs. Using prunings from these perennials as mulch allows yields of maize to stabilize at 2 tons/ha, three to four times more than maize grown without alley cropping (24). The prunings can also be used for fodder or fuelwood, depending on the farmer's needs.
- *Windbreaks (or shelterbelts)*: Continuous, uniform rows of trees are planted in crop fields perpendicular to the prevailing winds to reduce wind-induced crop damage, evapotranspiration, and soil erosion. In Niger, windbreaks have increased crop yields by 15 to 23 percent, even accounting for land taken out of crop production to grow the trees (19).
- *Live Fencing and Other Linear Plantings*: Trees or shrubs are used to form live fences

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[2] The material on agroforestry is based primarily on Roy T. Hagen's contractor report (app. A).

and hedgerows to mark field or garden boundaries, to control livestock movement, and to produce fuelwood and building material when they are pruned (53). Also, trees and shrubs can be planted on contour lines on sloping fields as a soil and water conservation practice. Linear plantings commonly are sited along roads, trails, and waterways (18).

In addition to these benefits, which lead to higher and more stable crop yields because of improvements in soil and water use, trees in agroforestry systems supply several products to resource-poor farmers and herders. An important product for livestock production is fodder. The protein-rich prunings can improve animal nutrition, which is considered a major constraint to improving the health of African livestock (see ch. 11). Agroforestry can supply numerous other products that may be consumed directly by a household or sold to generate income (18,53).

Agroforestry's contribution to the food security of resource-poor farmers and herders can be improved substantially. Development assistance for efforts to integrate agriculture, forestry, and livestock will be essential if this is to occur. Agroforestry programs have shown enough success to justify expanding such efforts. Key factors contributing to the potential importance of agroforestry systems are: 1) they fit well into existing African farming systems, 2) they meet numerous needs of resource-poor farmers and herders, and 3) these techniques are less capital-intensive than many other technologies.

The Role and Nature of Agroforestry

Agroforestry systems can help alleviate three of the most important constraints in African agriculture—low-fertility soils; insufficient, erratic water availability; and lack of animal fodder. Leaves from trees and shrubs, and to a lesser extent branches and roots, increase soil organic matter as they decompose. This organic matter improves soil structure, soil fertility, and soil water-holding capacity. The deep root systems of trees enable them to use nutrients in the deep soil layers. Some of these nutrients have leached down from the topsoil, a problem that is especially severe in degraded soils. The recycling mechanism of trees and shrubs brings these nutrients back to the soil surface where they again can become available to shallow-rooted annual crops (34,50).

Trees and shrubs used in windbreaks can increase water availability by reducing wind and thereby reducing evapotranspiration. Also, their vegetative canopies reduce the impact of heavy rainfalls, cut run-off, and thus increase infiltration of water into the soil. Also, more water remains available for plant growth because the shade provided by trees lowers soil temperature, which in turn acts to slow decomposition of organic matter (32).

By improving soils and increasing water availability, agroforestry systems contribute to higher and more stable yields of crops and forage. Tree and shrub prunings also contribute to livestock nutrition. Since poor nutrition is considered a major constraint to improving animal health, the protein-rich browse possible from agroforestry is an important consideration in promoting its use.

Agroforestry systems provide many of the products resource-poor farmers and herders formerly obtained from forests: firewood and charcoal; posts, poles, and construction wood; fruits, nuts and edible leaves; fiber for mats, baskets, and ropes; and plant materials for medicines, dyes, and cosmetics (18,53). These goods may either be used by the household or sold. These benefits of agroforestry will continue to grow in importance as remaining forested areas of Africa continue to succumb to human population pressures.

Dispersed Field-Tree Intercropping

Dispersed field-tree intercropping is the second most widely practiced general agroforestry technique in Africa. (Traditional shifting agriculture that relies on trees to restore soil fertility, is the most common.) Numerous variations exist on the mixture of species and the patterns in which they are planted.

The practice is used extensively by resource-poor farmers in semiarid regions, particularly in West Africa, "farm trees" are grown within and adjacent to crop fields. When natural regeneration is relied on, the trees appear to have a random arrangement. When clearing the bush for a new field, certain species are preserved. These most commonly are food-producing trees (fruits, nuts, leaves, etc.) such as the shea tree (*Butyrospermum parkii*) or the locust bean (*Parkia biglobosa*). Such savanna species, however, commonly do not regenerate well under natural field conditions (18).

Acacia albida is a particularly beneficial tree used widely in the semiarid areas of the Sahel. The most unusual feature of this nitrogen-fixing tree is that it loses its leaves during the rainy season, making it possible to raise crops, such as sorghum and millet, directly under the canopy of the tree with little competition for light. Crop yields are much higher under the tree than outside the canopy (table 8-4).

Acacia albida also benefits livestock production. Its pods and leaves provide more fodder per unit weight than meadow hay, rice straw, or groundnut tops (11), and *Acacia* fodder is produced during the dry season when annual grasses have disappeared (32). In addition, livestock concentrate near the trees and their manure further enriches the soil (32).

Where the proper balance has existed between *Acacia albida*, crops, and livestock, the system has been able to support several times the average human population for Sahelian West Africa (39). For instance, millet was continuously cropped in Sudan for 15 to 20 years in association with *Acacia albida*, compared to only 3 to 5 years without the tree (32).

Table 8-4.—Grain Yields Under the Crown of *Acacia albida* Compared to Grain Yields Outside the Crown[a] (kilograms per hectare)

Grain	Yield without *Acacia albida*	Yield with *Acacia albida*[b]
Millet	810	1,110
Millet	457	934
Millet	820	1,250
Sorghum	457	934

[a] Data is from Senegal and Burkina Faso.

[b] Twenty-five to forty mature trees per hectare.

SOURCE: Michael McGahuey, *Impact of Forestry Initiatives in the Sahel: Effect of Acacia albida on Millet Production in Chad* (Washington, DC: Chemonics International, January 1986).

Natural regeneration of *Acacia* is erratic and has declined over the past 20 to 30 years because of extended drought and grazing pressures. Few *Acacia albida* still exist in areas recently cleared for farming, but their number is slowly increasing in existing farm fields because some farmers are protecting the seedlings. It may take about 10 years before the new trees have much effect on crop yields, but the benefits last the remaining 70 to 90 years of the trees' lifespan (25). Even on old fields where the tree is common, the tree cover is often far below that which would give optimum yields (18).

The list of useful trees, however, does not end with *Acacia albiba*. For example, one investigation of trees and shrubs in the Sahel identifies some 114 multipurpose species. The use of *Balanites aegyptica* in agrosilvopastoral systems (i.e., that combine crops, trees, and livestock), or *Acacia senegal* in bush fallow systems, provides two more examples of traditional production systems that integrate trees (38). However, a combination of factors is contributing to the decline of many species, including species that have historically provided food during recurrent and critical food-shortage periods, or products for local use and

Photo credit: Mike McGahuey

The millet growing under this *Acacia* tree in Chad is denser, taller, and greener than that in the foreground because *Acacia* increases soil fertility and water availability for the intercropped cereal.

trade (44). Indigenous information on use of these resources is also being lost.

Alley Cropping

Alley cropping is a modern agroforestry technique developed from well-established traditional practices. Its precursor, the bush fallow system of shifting agriculture, is an indigenous form of agroforestry that has been practiced for centuries. Fields were cropped for several years followed by an extended woody fallow when deep-rooted trees and shrubs played a key role in restoring soil fertility. In the past, with low human population levels and land freely available, this represented an ecologically sound system of subsistence agriculture. Today, however, few areas remain where the population/land balance permits land to be left fallow for the necessary 15 to 30 years to restore fertility.

Scientists at the International Institute of Tropical Agriculture (IITA) incorporated the desirable features of bush fallow into a continuously productive farming system for the humid tropics. Rows of nitrogen-fixing trees or shrubs, such as *Leucaena*, *Gliricidia*, and *Calliandra*, are planted 2 to 4 meters apart, and the space between is planted in an annual crop like maize. The shrubs are pruned frequently, with the trimmings used as mulch, fodder, or fuelwood. Yields of maize stabilized at about 2 tons/ha after 6 years of continuous alley cropping; without alley cropping, the yield was no more than one-half ton/ha (24). An especially promising shrub for use on waterlogged soils is *Sesbania rostrata*, native to Africa. Rice yields were increased 55 percent with the addition of the *Sesbania* prunings, comparable to the addition of 120 kg nitrogen/ha (33).

Although experimental results such as these indicate the technical feasibility of alley cropping, farmer acceptance and adoption is in the early stages of evaluation. Alley cropping is more labor-intensive than traditional methods and requires a considerable change in farming practice. Farmer participation in farm trials organized by IITA and the International Livestock Center for Africa has been enthusiastic, however (19). Of particular interest is the evidence of farmer adaptation and experimentation with introduced agroforestry systems, suggesting the ability to tailor systems to variable circumstances and needs (37).

Alley cropping probably will find its greatest acceptance in areas where land scarcity is the most acute, that is, where shifting agriculture is no longer possible. It will require adaptive research for the seasonally humid and highland areas and major modifications before it can be used in the semiarid zone where water competition between trees and crops would be a constraint. Furthermore, none of the species used for alley cropping in the humid zone seem suitable for the non-irrigated semiarid zone, and likely alternatives are not readily apparent. This is especially true for hardy, fast-growing nitrogen-fixers (18).

Windbreaks (or Shelterbelts)

Windbreaks are uniform rows of trees planted in fields perpendicular to the prevailing winds to reduce evapotranspiration, soil erosion, and wind-induced crop damage. Windbreaks are a virtually unknown practice in traditional low-resource agriculture in Africa, but are receiving some attention among the development agencies. The Majjia Valley Windbreak Project in Niger is one of the most successful projects in the Sahel. The project, begun in 1975 with the assistance of the private voluntary organization CARE, has established about 350 kilometers of windbreaks to protect some 3,000 hectares of rainfed millet and sorghum fields (10). Early evaluations of this project indicate that crop yields had increased 23 percent, while a more recent estimate is that they increased 15 percent. Both estimates take into account the 6 percent of farmland "lost" to trees. The most likely explanation for the differing estimates is that the trees are now larger, depressing crop yields by causing more shading and competing for nutrients (53).

The small average field size and the need to orient the windbreaks perpendicular to prevailing winds makes it impractical for an individual farmer to establish windbreaks. To be successful, a group of farmers, ideally an entire village as was done in the Majjia, must cooperate in the effort so that windbreaks can extend across adjoining fields. Another constraint in windbreak establishment is that they need protection from livestock. Livestock in semiarid regions usually are left to roam freely during the dry season. Windbreaks or other field plantings dispersed over large areas are difficult to protect from grazing. The villagers in the Majjia agreed not to allow grazing during the approximately 3 years required for the tree branches to grow out of the reach of livestock. This was enforced by guardians hired with project funds. Also, rights to the trees can be controversial; ownership of the windbreaks in the Majjia Valley and the distribution of wood products harvested from them are still unresolved 13 years after the project's start (18).

The Majjia Valley project started out in response to a request for assistance from local villages. It began on a small scale working closely with forest service agents and villagers. The project has developed enthusiastic support from villagers who have seen the benefits firsthand. Now 60 farmer-owned, private nurseries exist in the valley and these help respond to requests for assistance from surrounding villages (19). Periodic partial harvesting of the windbreaks could make the participating villages largely self-sufficient for their wood needs (18).

Live Fencing and Other Linear Plantings

Another agroforestry approach is to use trees or shrubs to form live fences or hedgerows to mark field or garden boundaries and control livestock movement. These also can be pruned to produce fuelwood and building materials (53). Live fencing requires a large number of closely spaced plants and frequent pruning. The use of live fencing varies greatly between regions. In some places it is almost unknown, yet in the Fouta Djalon Highlands in Guinea there is a social caste who make their living establishing live fencing (18).

Live fencing, although labor-intensive to establish, provides a low-cost alternative to metal fencing (27). Fences in the semiarid regions formerly were made with readily available thorn bushes chopped down and arranged where needed. With desertification and increased demands on resources, thornbushes are increasingly in scarce supply. Thus, live fencing could be advantageous, especially around dry-season gardens which must be protected from free-ranging livestock. Unfamiliarity with live fencing techniques seems to be a significant constraint in many areas.

Other linear plantings do not necessarily have to be as densely planted or require as frequent pruning as live fencing. Encouraging the planting of multipurpose trees and shrubs along field margins often is easily achieved because many farmers want to define the limits of their property clearly. Field border plantings may be a first step toward more integrated (e.g., of crops, trees, and livestock) agroforestry techniques. A second step can be planting trees and shrubs on contour lines on sloping fields as a soil and water conservation practice. Linear plantings also commonly are established along roads, trails, and waterways (18).

Potential for Adoption

Agroforestry offers strong potential because it tends to fit well into existing African farming systems and meets numerous needs of resource-poor farmers and herders. Agroforestry can contribute to improved management of soil and water resources, leading to increased, more stable yields. The multiple benefits—food, fodder, fuelwood, building materials, and income—possible from agroforestry systems also can reduce pressure on natural forest and grazing lands.

Agroforestry techniques are rarely capital-intensive compared to many other technologies, thus encouraging farmer and herder experimentation and adoption. If seedlings are provided by a service or project, the main inputs from the farmer or herder is labor. An important fringe benefit of agroforestry development is that by increasing soil organic matter it enhances effectiveness and reduces potential waste in commercial fertilizer applications. Most tropical soils are characterized by highly

Photo credit: Mike McGahuey

Live fencing protects gardens and prevents the deforestation that arose from cutting thorn bushes for fences.

oxidized, low activity clays that are unable to bind nutrients in a form usable to the plants. The addition of organic matter to the soil improves its ability to retain fertilizers until crops can make use of them.

Newly developed, synthetic, water-absorbing polymers applied to form a water-absorbing layer at the root zone may prove to be instrumental in afforestation efforts, particularly in the arid/semi-arid zone. In experiments conducted in Sudan, the survival period of tree seedlings was increased fivefold when polymers, able to hold 400 times their weight in water, were used in the soil mixture. The present survival rate for tree seedlings in Sudan is no more than 50 percent and in Ethiopia the performance is even worse, with only 15 percent survival recorded among 500 million seedlings. At a cost of 14 to 22 cents per tree, the new technique could be a cost-effective way of improving afforestation efforts (8).

Despite its promise, development assistance agencies have become interested in agroforestry only recently. PVOs, and CARE in particular, have been innovators in agroforestry. CARE has 13 agroforestry projects in 11 African countries (26). Few projects are as much as 10 years old, but these have already made substantial progress toward developing stable, sustainable farming systems. It appears that development agencies have only scratched the surface of agroforestry's potential for improving the lot of the resource-poor agriculturalist in Africa.

Problems and Approaches

Integrating Agriculture, Forestry, and Livestock

One of the most serious obstacles to promoting agroforestry as a sustainable land-use system is institutional. The fact that agricultural education and administration typically are pursued along narrow disciplinary lines creates fundamental problems for agroforestry—by definition an integrated production system requiring interdisciplinary research. In simplest terms, the dilemma this creates can be characterized the following way:

> Agroforestry is institutionally considered a sub-division of forestry. Forestry institutions deal with forestry and forest land. The major potential of agroforestry lies in the integration of trees into agricultural and pastoral lands. The development of these lands is the mandate of agricultural institutions. Agricultural institutions are not mandated to deal with agroforesty (29).

Even forestry departments have until recently shown considerable reluctance in promoting agroforestry. Foresters now seem more willing to support agroforestry, realizing that farmers faced with insufficient crop yields will not devote land and energies to tree plantations solely for firewood production. Those few projects such as the Majjia Valley Windbreak Project that have involved tree planting on farmers' fields to increase crop yields have enjoyed much greater success than projects that have just emphasized maximizing wood volume/ha/year.

The agriculture, livestock, and forestry services of most African governments are as strongly separated among disciplines as, and in part because they reflect, their Western country counterparts (53). The need to improve integration of these agricultural activities is particulary important in the case of African agriculture. Such institutional changes cannot occur overnight, but increased integration and cooperation among disciplines could be strongly encouraged, among agricultural as well as social sciences. For example, development assistance could ensure that participation by all relevant government services be negotiated in the project planning stage, even though this may make the project administratively more burdensome. Funding could be provided for multidisciplinary agroforestry workshops that include foresters, agronomists, livestock specialists, and social scientists.

The number of schools offering agroforesty courses in developed countries is increasing, but still is small. Probably no more than six universities in the United States offer instruction in agroforestry, usually a single, recently created, course (46). This shortage is paralleled in Africa. Development assistance agencies could support agroforestry courses as part of degree programs in tropical forestry. AID, for example, could provide funding to selected U.S. universities to develop or bolster agroforestry curricula. Support for regional agroforestry schools for the different agroecological zones could also be promoted.

Obstacles of Land and Tree Tenure

Farmers rarely will plant trees, let alone protect and care for them, if they have no assurance that they will reap the benefits. This makes agroforestry difficult for those farmers who lack secure rights to their land. Few poor farmers actually hold title to the land they cultivate, as central governments generally claim most of the land. In practice, however, most of the farmland is passed down from one generation to another and remains under family control (18).

A large percentage of farmland in some areas is cultivated by families who borrow or lease farmland. The landowner in such cases may forbid tree planting by the tenant if local custom associates tree planting with land tenure rights. Lack of land and tree tenure is especially problematic for women, who could benefit greatly from having an improved, more accessible supply of fuelwood and fodder. Even where land tenure is well defined, land and tree rights may be separate.

Communal farmland has also been the target of a number of efforts to mobilize tree planting efforts, but the track record of these efforts is not good. What belongs to the group is no one individual's responsibility, and the care and protection needed by young trees is too often lacking on communal lands (18). The problem can be particularly acute in the case of communal grazing areas. Development assistance efforts will be more successful when they take local land- and tree-tenure practices into account in the design of agroforestry projects. The rights to use the trees need to be defined as part of the project design. African governments may need to reassess their land tenure and forestry legislation if agroforestry is to reach its potential.

Encouraging Investment in Agroforestry

The payback period varies considerably for different agroforestry techniques. Alley cropping may start to improve yields during the first year or two. A live fence, if managed properly, may become effective in 1 or 2 years. Windbreaks may begin to produce results in 3 or 4 years. Some fruit trees used for intercropping may begin to bear fruit in 3 years. The shorter the period before benefits are realized, the more likely farmers are to invest scarce land, labor, and capital in agroforestry initiatives. Thresholds of investment are obviously highly variable and will depend on such factors as level of investments required, added risks that may be created, how and to whom benefits are derived, or previous experience with innovation. A better understanding of these economic trade-offs from the farmers' point of view is in itself an important research area that could also help "calibrate" research priorities in experiment stations to what is needed and adoptable by farmers.

Other agroforestry techniques may take much longer to produce a return on investment. For example, *Acacia albida* intercroppping may yield few benefits for the first 10 years, although the long-term benefits may be very substantial, particularly in light of increasing demands being placed on the resource base. Few resource-poor farmers have the luxury to approach investment decisions using such a long-term perspective, however. Under such circumstances, supporting agencies may need to underwrite costs until farmers and herders begin to realize benefits. Expanding markets for agroforestry goods also may provide incentives and support the sustainability of such efforts. In other cases, however, continued support may depend on more permanent forms of government incentives or restrictions, the costs and benefits of which should be viewed within the context of long-term national interests in sustaining the natural resource base.

Support for Decentralized, Locally Managed Nurseries

Most seedlings for agroforestry plantings are produced in central nurseries, usually in cooperation with national forest services. Without development assistance, forest services of many African countries are incapable of producing and distributing the quantity of seedlings necessary for large-scale plantings. More importantly, many are not capable of helping large numbers of widely scattered farmers, each needing small-scale plantings. Even if farmers accept a particular agroforestry technique, it will do little good if they have no source for the required seedlings. Improving local capacity to produce seedlings would give farmers better control over access to desired tree species, and would greatly reduce the significant logistical and transportation problems involved with centralized nurseries. A few projects have begun to encourage and support the creation of local village, school, and private nurseries. The CARE Koro Village Agroforestry Project in Mali, the AID Community Forestry Project in Guinea, and the Somalia Community Forestry Project are examples (box 8-1).

Box 8-1.—Community Agroforestry in Somalia

For the first time, women have become an important force in a major agroforestry project in northwest Somalia—an area hit hard by desertification and a fuelwood crisis. At least 7,000 people, including members of the Somali Women's Democratic Organization (SWDO), the National Range Agency (NRA), and local residents and refugees have learned a variety of skills that can be used in future development work. In addition to planting some 300,000 trees, skills have been learned for establishing and managing local nurseries, collecting and analyzing data, and coordinating large community-based reforestation and conservation activities. Some 60,000 persons have benefited in 2 years.

Associated enterprises include producing and marketing fuelwood and growing vegetables between rows of newly planted trees. The trees fix nitrogen in the soil; protect the vegetables from wind and soil erosion; and produce green manure, mulch, and firewood. The firewood provides fuel, and the vegetables improve diets, and both will be marketed by the women. Feasibility studies are also looking at beekeeping/honey production as another income-generating enterprise because the trees' flowers attract large numbers of bees.

The communities involved want to expand their forestry and agriculture activities. Plans for water reservoirs and irrigation systems are underway. The Overseas Education Fund (OEF) has provided extensive training to SWDO members and NRA extension agents in program design, implementation and management, technical agroforestry, and small business management and marketing to enable them to carry out programs in other parts of the country. Training materials have been published for use in similar efforts in the region.

A factor in the success of this project is the government of Somalia's recognition of the importance of conservation issues. This region of Somalia has suffered for many years from severe drought and desertification caused in part by mismanagement of natural resources. Because of the scarcity of trees, supplies of the region's most important source of fuel—firewood—were very low and were further depleted by an influx of refugees from Ethiopia. In response to this crisis, the government developed a 5-Year Plan (1982-86) which gives anti-desertification and forestry top priority. OEF, in turn, launched this 2-year pilot agroforestry project with funding from AID.

The refugees are mostly women and children who came from Ethiopia. While only 43 percent of the over 500 Ethiopian refugees and Somalis hired from the local communities are women, this is considerably more than the usual number of women engaged in paid manual labor in rural Somalia. This is probably the first time that the men in the project have had so many female co-workers, or that so many had access to training in technical and management skills.

SOURCES: Overseas Education Fund International, Washington, DC, Press Release, Dec. 11, 1986; OEF International *Annual Report*, 1986; OEF International *Final Report: Community Forestry for Refugee Related Areas*, 1987.

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Chapter 9

Crop and Livestock Genetic Improvement

CONTENTS

Page
Summary 213
Crop Breeding 215
  The Potential of Specific African Crops 215
  Potential of Crop Breeding 220
  Problems and Approaches 221
Animal Breeding 226
  The Potential of Specific African Animals 227
Chapter 9 References 231

Boxes

Box *Page*
9-1. Definitions of Common Breeding Terms 213
9-2. Biotechnology's Impact on African Agriculture 222

Figure

Figure *Page*
9-1. Potential Improvement Pathways for Traditionally Managed Small Ruminant Flocks on Maasai Group Ranches 230

Tables

Table *Page*
9-1. Grain Yield Per Hectare by Region, 1950-52 and 1980-82 214
9-2. Research Expenditure as Percentage of Product Value, by Commodity, for Selected Countries in Different Regions of the World 225
9-3. Endangered African Cattle Breeds 229
9-4. Poultry Productivity Under Different Management Systems 231

Chapter 9

Crop and Livestock Genetic Improvement

SUMMARY

Historically, agriculture has benefited from and relied on breeding and genetic adaptation to improve crops and livestock. For some 10,000 years, farmers and herders have selectively chosen offspring from those plants and animals that performed well. In time, breeding became a highly sophisticated science. Eventually, agriculture evolved from choosing the most appropriate crops and animals for the environment to altering the environment to improve animal and plant growth and nutrition.

Low-resource farmers and herders have developed considerable expertise in the manipulation of agricultural environments to enhance and stabilize plant production. These activities primarily involve adapting micro-environments to their needs through such practices as shading, mulching, and wind protection (43). Farmers also engage in some of the steps in plant breeding, making selections within plant varieties in order to take advantage of differing micro-environments (e.g., type or moisture content of soil). This process of fine-tuning varieties to local environments, is largely responsible for the high degree of genetic diversity in traditional varieties and landraces (see box 9-1).

Box 9-1.—Definitions of Common Breeding Terms

Local varieties or breeds (also called traditional varieties or landraces): All varieties and breeds that are grown today, even in the most isolated areas of the world, have benefited from continuous selection by farmers and herders. Local ones, however, are considered "unimproved" to contrast them to those that have been "improved" by modern scientific research.

Improved varieties or breeds: Varieties and breeds developed through scientific research. One major difference between improved and local varieties and breeds is that the former have more identifiable and uniform traits, which can be replicated more closely.

Open-pollinated improved varieties: A subset of improved crop varieties distinguished from hybrids in that the farmer is able to set aside some of the harvest to use as seed the following year. The technique for developing these varieties generally consists of bringing together a gene pool of varieties within which most of the desired traits are represented, and upgrading the uniformity and level of performance of the pool by systematic selection.

Hybrids: Hybrids are a subset of improved crop varieties that result from crossing separate pure lines. Improvements typically are much greater than for other improved varieties, but because they do not retain their superior performance in subsequent seasons, new seeds must be bought each year in contrast to open-pollinated varieties.

HYVs: High yielding varieties are another subset of improved varieties. HYVs are bred to respond to increased inputs and are typically short-stemmed, allowing them to produce more grain without tipping over. When crop plants fall they become more difficult to harvest and more susceptible to pests and diseases. HYVs, associated with the Green Revolution, were bred to take advantage of irrigation and fertilizer.

Crossbreeding: Any livestock improvement system that aims to exploit the complementarity between two distinct breeds or varieties.

With the advent of new agricultural technologies and inputs, the balance between adapting varieties to suit the environment v. adapting environments to suit the varieties shifted heavily toward the latter. Far greater manipulation of the environment was undertaken, such as wide-scale regulation of water, nutrients, and pest populations. The shift is best illustrated by the Green Revolution technologies, where the performance of high-yielding varieties (HYVs) were predicated on extensive use of irrigation, fertilizers, and pesticides. Equivalents in the area of livestock development included veterinary intervention or disease eradication programs to enable higher producing breeds to survive where they previously could not.

Disappointing results in Africa's ability to benefit from these Green Revolution technologies has led to reexamination of strategies for increasing crop and livestock productivity in African farming systems—in particular crop and livestock breeding. Africa has been largely bypassed by the Green Revolution as well as by more conventional plant and animal breeding (9,10) (table 9-1). Much of the continent has low water availability, infertile soils, and severe pest and disease problems. Except for restricted cases, institutional and economic limitations prevent the use of the Green Revolution technology packages designed to compensate for these serious environmental constraints. Only about 1 percent of Africa's cereal farmland is used to grow high-yielding varieties, and only about 10 percent is growing improved varieties (48,59). A similar situation exists for animal breeding, which has had little impact on resource-poor farmers and herders in Africa.

Breeding, however, can be expected to make a major contribution to agricultural development in the future. For example, new improved crop varieties exist that can reliably increase yields because of their resistance to major pests and diseases. Dramatic increases in milk production have been made possible in some favorable regions by crossing African breeds with exotic dairy breeds. Based on agricultural development outside of Africa, and preliminary accomplishments within Africa, research to improve crops through genetic improvement represents one of the best investments for enhancing low-resource agriculture. This is less true for livestock, however, where improved management (e.g., attention to nutrition, disease, and climatic stress) is a prerequisite to gains through genetic improvement (6). Goats and sheep, however, show considerably greater promise than cattle (33).

Realizing the full potential possible from genetic improvements will require changes in many segments of the agricultural economy, such as improving incentives for farmers and herders to increase production, and making it more cost-effective to adopt improved varieties. Several necessary changes closely related to breeding include:

- decreasing the wide gap that currently exists between on-station and on-farm results,

Table 9-1.—Grain Yield Per Hectare by Region, 1950-52 and 1980-82

Region	Average annual yield (kg) 1950-52	Average annual yield (kg) 1980-82	Change (percent)
North America	1,646	3,757	+128
Western Europe	1,733	3,843	+122
East Asia	1,419	2,973	+109
Eastern Europe	931	1,819	+ 95
South Asia	825	1,450	+ 76
South America	1,217	1,854	+ 52
Africa	**757**	**1,044**	+ **38**
Australia*	1,100	1,301	+ 18
World	1,186	2,247	+ 89

*Data are for 1981-83.

SOURCE: U.S. Department of Agriculture, Economic Research, *World Indices of Agricultural and Food Production, 1950-1983*, unpub. printout (Washington, DC, 1984), cited in L. Brown and T. Wolf, *Reversing Africa's Decline* (Washington, DC: Worldwatch Institute, 1985).

- choosing appropriate breeding strategies that more closely reflect the conditions and potentials of low-resource farmers and herders,
- establishing a better match between research funding for agricultural commodities and their importance for Africa's food security, and
- addressing needs for improved seed multiplication and distribution.

Several factors restricting wider use of improved varieties, for example, poor transportation and marketing infrastructure, will require a long time to resolve. In the meantime, affordable, immediate, and significant advances can be obtained by improving agronomic and livestock management practices for traditional or improved varieties (4,14,34,57). Since inefficient practices sometimes are the limiting factors, improvements in them may outweigh those from plant or animal breeding. Even so, the gains resulting from the use of these improved practices for improved varieties typically are greater than for local varieties.

CROP BREEDING[1]

Crop breeding is the process of selecting traits from parent plants to produce offspring that are "better" according to some predetermined criteria. The most important objectives for crop breeding for resource-poor farmers in Africa include:

- higher yielding under farmer conditions;
- yield stability from season to season;
- pest and disease resistance;
- tolerance to environmental stress;
- improved quality, storage, and ease of processing; and
- adaptation to diverse cropping systems, including intercropping.

Breeding objectives may differ according to clientele. A variety used primarily for home consumption (often grown by women) would probably concentrate on yield stability, storage and processing characteristics, and nutritional quality. When breeding a variety for cash generation (often produced by men), it may be more appropriate to emphasize responsiveness to management and inputs.

Maintenance research is necessary to sustain breeding improvements and it can require as much money and time as it took to develop the improvements initially (39). Also, when an improved variety is introduced into a new environment, a minor pest may cause unanticipated damage, necessitating additional research to improve host resistance.

The Potential of Specific African Crops[2]

Millet

Millet is grown on 15.5 million hectares in Africa, producing 8.8 million metric tons of food grains per year (47). Although it is often grown with sorghum in the arid/semi-arid zone, millet can be produced in areas too dry even for sorghum. Two species—pearl or bulrush millet (*Pennisetum americanum*) and finger millet (*Eleusine coracana*)—native to Africa account for 95 percent of production, the former being about four times as prevalent. Pearl millet is the only major food crop that can be grown on the sandy soils from Senegal to Sudan. It is also grown in the drier areas of eastern and southern Africa, but production there is only one-fifth that in West Africa. In contrast, finger millet is grown in the moister areas of eastern and southern Africa, principally in Kenya, Uganda, Tanzania, Malawi, Zaire, Zambia, and Zimbabwe (40). Alternative crops such as sorghum and maize are also commonly grown in these moister areas.

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[1] This material on crop breeding is based primarily on OTA contractor reports prepared by David J. Andrews, University of Nebraska, Lincoln, NE; Fred R. Miller and John A. Mann, Texas A&M University, College Station, TX; Sherman F. Pasley, University of Florida, Gainesville, FL; Ivan W. Buddenhagen, University of California, Davis, CA; Walter A. Hill and Conrad Bonsi, Tuskegee University, Tuskegee, AL (app. A).

[2] Where the potential of improved varieties is discussed, it is based on estimates of crop breeders contacted by OTA, and data on current yields from the U.N. Food and Agriculture Organization (FAO). Estimates assume the use of improved seeds and improved management practices. These discussions are often framed around yield enhancement, but it is important to note that these yield estimates take into account improvements that also reduce losses to pests, drought, etc.

Other African millet species are of restricted local importance; for example, "Iburua" or "Fonio" (*Digitaria iburua*) is an important famine food in several west African countries and "Tef" (*Eragrostis tef*) production is about 145,000 tons/year in Ethiopia.

Millet production currently averages about 500 to 700 kg/ha/yr but this could be doubled in 20 years by a combination of new varieties and improved cultivation practices (4). Convincing theoretical, experimental, and on-farm evidence exists to support such claims (16).

Genetic improvement could increase yields by perhaps 1 percent per year. Yield potential in unimproved varieties exceeds 3 tons/ha/yr (28,29). Currently, however, these landraces produce a low proportion of grain compared to total plant biomass, therefore much of the breeding effort is directed to improving this ratio. Higher yielding and disease-resistant varieties of pearl millet are now grown on half of India's 11 million hectares. Yield increases of 20 percent were obtained over the last 2 decades from crosses between African germplasm and Indian breeder stocks. Similar sources of variability also have great potential in Africa but are more difficult to exploit because Africa faces greater disease and pest problems.

A number of improved varieties have been released in Africa, but widespread adoption of these varieties has not occurred. However, the precise extent of adoption is not well-documented and the degree of farmer-to-farmer spread not known. It is doubtful that more than 10 percent of any African country's cropland is planted in improved varieties, although this figure may be higher in Senegal (4).

On-farm evidence shows that large differences in yield exist between adjacent fields belonging to different farmers. Since both receive the same rainfall, the major difference is attributed to management and previous cropping history. The best fields in a given locality already are giving double the average yield. Many agronomists agree that low soil fertility and inadequate, untimely management, not crop-water availability, are currently the major on-farm factors restricting production (16).

Sorghum

Sorghum evolved in north-eastern Africa some 2,000 to 4,000 years ago. The sorghum belt extends from approximately 7 to 15 degrees north latitude from the west coast to the east coast. It is the primary source of dietary energy for the majority of the region's poorest people.

Although sorghum is thought of as a crop for arid and semi-arid regions, it is also important in some wetter areas: the highlands of East Africa from Ethiopia to Burundi and Rwanda; semi-humid areas of West Kenya and Uganda; and in areas of the Guinea Savanna in West Africa. It is the first or second most important cereal grain in much of Africa, sharing importance with millet throughout the arid/semi-arid zone and with maize in the wetter areas.

Sorghum breeding is an art as old as the crop, but rather young in terms of modern science. The germplasm base is extremely broad, but still vastly underused, and since sorghum is of African origin, Africa stands to benefit greatly from additional research.

Plant breeders do not agree on the extent to which current sorghum yields can be increased. Part of the disagreement arises because the estimates are derived from different starting points —sorghum is grown under a wide range of environmental and management-intensive conditions. Based on a weighted average of U.N. Food and Agriculture Organization data for Sub-Saharan Africa, the average yield for sorghum is 780 kg/ha/yr (49). Productivity in Sudan is about 20 percent lower than the average, while neighboring Ethiopia averages 1,350 kg/ha/yr (49). Gains of between 50 and 100 percent are possible on fertile soils with moderate rainfall simply by using existing improved varieties (34). The 100 percent estimate, a doubling of the current level, assumes 10 to 15 years of additional

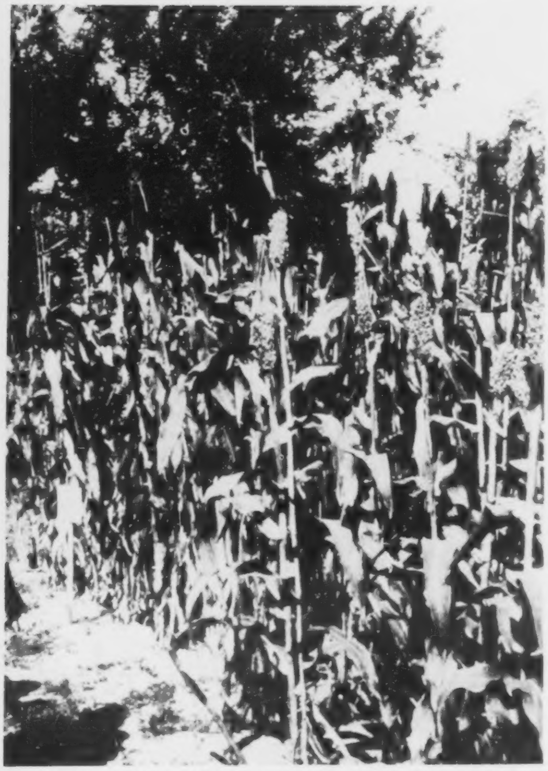


Photo credit: Dale Bottrell/Consortium for International Crop Protection

Sorghum is an important cereal grain in most of Africa and its growers stand to benefit greatly from improved varieties.

successful breeding improvements. Related improvements in management could result in yields of 4,000 to 8,000 kg/ha/yr in areas of reasonably good soil conditions, with yields reaching half this level on the acid soils of Mali, Niger, and much of West Africa (34). Other researchers are less optimistic, perhaps because their focus is on the difficulty of extending the entire package which consists of the new variety, new management practices, and increased use of inputs such as fertilizer. These more pessimistic views place possible production levels at between 1,500 to 3,000 kg/ha/yr using improved varieties and management practices (3,32,41).

Sorghum hybrids are uncommon except in Sudan and Zimbabwe. The adoption rate for hybrids and other improved varieties in most of East Africa is only 5 to 10 percent, and it is even lower in West Africa (34). Some crop breeders believe that hybrid sorghum is appropriate only for a small area of Africa, and that research and extension efforts should reflect this, placing increased emphasis on improving non-hybrid sorghum varieties for most of Africa (34).

Maize

Maize, although not native to Africa, is planted on more land than any other cereal (56), and it is undoubtedly the most important grain in the subhumid tropical uplands and the highlands. Its ecological requirements overlap considerably with sorghum, but it is not as drought tolerant. Maize consumption tended to be restricted to urban areas in the past, perhaps because of food aid and imports. Increasingly, however, maize is becoming more widespread, a trend that is likely to continue given its productivity.

Maize yields in different African countries vary dramatically but the average is 1,160 kg/ha/yr (49). Countries that do not make wide use of improved seed typically average 600 to 700 kg/ha/yr, whereas in Zimbabwe where improved seeds are used the average is nearly three times higher (49). Estimating the potential increases in yield for low-resource farmers is difficult, however. Adoption rates for improved maize are generally high, so maize yields could double in many areas in the near future (17,38). The continued spread of hybrids that began in the mid-1960s should allow even greater increases (56,60). The area planted to hybrids in Kenya, Zimbabwe, and Zambia is exceptionally high, and can be attributed to the advanced infrastructure, incentives, and inputs that favor the use of improved maize in these countries. The estimated amount of land in Africa now devoted to Kenyan and Zimbabwean improved maize varieties could be doubled (49).

Nigeria is making extensive use of disease-resistant maize materials developed by the International Institute of Tropical Agriculture. In addition, recently developed Tanzanian and Zambian varieties and hybrids are streak-virus resistant and will be useful in large areas in neighboring countries (17). Breeders have had little success in increasing maize tolerance to drought, but several improved varieties mature more quickly than local varieties and, therefore, are less affected by the onset of the dry season.

Rice

Two species of rice are grown in Africa: Asian rice (*Oryza sativa*), which was introduced, and African rice (*Oryza glaberrima*). Rice is the fourth most common crop in Africa in terms of hectarage after maize, millet, and sorghum (56). It is grown throughout Africa wherever water is adequate, including river basins within the arid and semi-arid zone. However, it is a major food crop of only a few African countries.

Three major forms of rice cultivation can be distinguished for Africa: dryland, wetland, and irrigated. Dryland (or upland) cultivation is practiced where rain is the only source of water. It comprises about 40 percent of the paddy production in Sub-Saharan Africa's 15 major rice-producing countries. Wetland cultivation (e.g., in swamps, mangroves, and deep water) occurs in all four major agroecological zones and represents about 45 percent of paddy production. Only about one-sixth of the region's rice is produced using modern irrigation and, 60 percent of this occurs in just one country—Madagascar (51).

Dryland rice, which occupies about half the area planted to rice in Africa, is low yielding and depresses the 1,450 kg/ha annual average for rice in Africa (49). Some improvements have been bred into dryland varieties (60), and additional research emphasizing disease resistance is justified. Greater potential exists, however, for improving rice production in other agroecological zones (7). High-yielding varieties are used on approximately 4.7 percent of the area planted to rice (9). For these rice production systems, as for dryland rice production, breeding for disease resistance is important.

Yields could be increased in many areas by improving water control, but significant problems hinder irrigation in Africa (see ch. 7). Expansion into wetland areas offers the greatest potential for production increases. However, current rice improvement efforts for Africa do not reflect this (7).

Food Legumes

A diverse group of legumes are grown as crops in Africa, including cowpeas, common beans, lima beans, soybeans, groundnuts (peanuts), bambarra groundnuts, pigeon peas, chickpeas, and a number of other minor species. One or more legumes grow in each agroecological zone, and many of these crops can be grown under a wide range of ecological conditions. Bambara groundnut, for example, is one of the most drought-tolerant legumes, but it also grows in the rainforest environment and in cool, moist highlands. Typical of other food legumes, this crop contains two to three times more protein than cereals, yet it is considered a "poor people's crop" and is among the most neglected by science (35). Legumes are also valuable sources of oil, and are important in animal nutrition.

Many legumes are able to fix nitrogen and, therefore, can thrive in nitrogen-poor soils. This ability makes them well-suited to crop rotations and enhances their benefits in intercrop situations.

The major research emphasis has been and should continue to be stabilization of production through increased disease and pest resistance, development of short-cycle varieties, such as the 60-day cowpea variety developed by the International Institute of Tropical Agriculture, and improved nitrogen-fixing ability. Major advances in yield potential may be possible, but will be secondary to these other considerations (7). Potential also exists for expanding the use of legumes into new areas; for instance, lima beans could be introduced to the seasonally or continuously humid tropics, pigeon peas could be used in the arid/semi-arid zone, and chickpeas could be grown in the highlands.

Roots, Tubers, and Plantains

Root and tuber crops are major sources of food energy for at least 200 million people in Sub-Saharan Africa, particularly in the humid and highland areas (5). For example, they account for at least half the calories in people's diets of Zaire, Congo, and Gabon (56). Many of these crops are efficient producers of calories, much more so than maize on a per-hectare basis. For example, compared to maize, cassava produces 2.2 times as many calories/ha; yams produce 2.7 times as much; and sweet potato produces 1.5 times as much (52).

Cassava (*Manihot esculentum*) is the most widely grown root crop, and it is adaptable to a wide range of agro-climatic and soil conditions. It is able to survive on marginal soil and so is often grown as the last crop in a rotation sequence, before the land must be abandoned to fallow. Even though it can be grown under humid conditions, cassava is fairly drought tolerant (20). Cassava accounts for approximately one-third of the total staple foods produced in Africa and its leaves are a preferred green vegetable that provide high-quality protein, minerals, and vitamins (52). It can be stored in the ground safely for up to 36 months, thus making it available to farmers anytime of year (18).

The tolerance of cassava to extreme stress, its efficient production of calories despite low-resource requirements, and its year-long availability and compatibility with other crops will continue to make cassava an important component of diversified farming systems (20). Cassava yields in Africa average 6.4 t/ha/yr, compared to the world average of 8.8 t/ha/yr (19). Improved varieties exist that are high-yielding, resistant to disease and insect pests, good quality for consumer acceptance, and low in cyanide content. The amount of land planted with these improved varieties is still very low in Africa, but their use is increasing as evidenced in Nigeria (22).

Yam (*Dioscorea spp.*) requires fertile soils and is produced chiefly in the more humid countries of West Africa. Africa produces an estimated 96 percent of the world's yams, concentrated in Africa's "yam zone:" Nigeria, Benin, Togo, Cameroon, Ghana, and the Ivory Coast (18). Despite the high labor cost to produce yams, it is a preferred food in these countries, a highly valued cash crop, and an important source of income for resource-poor farmers (22). Although almost all yams produced are local varieties, adoption of improved varieties may spread with the help of a recently developed method of producing "seed" yam (conventional tubers used for planting weigh about 800 grams, whereas the new ones weigh about 30 grams). The "minisett technology," as the International Institute of Tropical Agriculture has labeled this breakthrough, can increase the amount of planting material available, shorten the period during which the land is occupied with yams, and allow for healthier plants and more uniform stands. The end result has been higher yields and economic returns (5).

Sweet potato (*Ipomea batatas*) is grown through out Sub-Saharan Africa, but is a major staple in only a few countries: Burundi, Rwanda, and Uganda. Although it grows well under a variety of ecological conditions, its sweetness limits its acceptability (22). As with cassava, the crop can be used for animal feed as well as human consumption. Improved sweet potato varieties exist that are resistant to weevil, disease, and nematodes, but adoption rates remain low (22,25).

Aroids such as cocoyams (*Xanthosoma spp.* and *Colocasia spp.*) require an ample water supply and, thus, tend to be concentrated in areas of high rainfall. They are important in four of the humid countries: Cameroon, Ghana, Gabon, and Nigeria (52). Although several clones of cocoyam resistant to diseases have been identified and are being incorporated into breeding programs, virtually no improved varieties are being used by farmers (22).

Plantains also are widely grown, particularly in forest areas and in home gardens. They are a major energy source in a few rural areas such as those in Rwanda and Uganda. Plantains are an ideal crop to raise following forest clearing because they need little land preparation and they provide useful cover within intercrops. Plantains can be grown on steep slopes unsuited to root crops and cereals (52).

Although cassava can be stored underground, most root, tuber, and plantain crops are difficult to store. In terms of production, yield enhancements are most likely from efforts directed at increasing pest and disease resistance. Improvements in quality, for example, reducing the cyanide content of cassava and the sugar level in sweet potatoes, is another promising avenue for plant breeding (22).

Potential of Crop Breeding

> The genetic code carried in the seed is especially valuable to the farmer with limited resources, since this is potentially one of the least expensive inputs that can be purchased for a large area (15).

The potential benefits to resource-poor farmers in Africa from crop breeding are high. Improved varieties offer a relatively inexpensive way to improve productivity markedly (4,15). A combination of factors are beginning to offer hope for higher, more stable yields: resistance to several pests and diseases has been bred into many major crops; new crops can make more efficient use of internal and external resources; and more quickly maturing varieties allow additional flexibility in crop rotations and increased stability under variable and often adverse climatic conditions. New priorities in research, if they can be fostered, could lead to substantial improvements in food quality, processing, and storage.

Significant improvements can be expected to result from breeding because comparatively little research has been done on African crops, so the potential seems virtually untapped. Landraces—unimproved varieties now in use—are well adapted to produce high-quality grain and maximum biomass from limited resources. However, they often are inefficient in terms of maximizing grain production. Landraces typically have harvest indexes (the proportion of grain biomass to total plant biomass) of about 20 percent while HYVs can reach 40 percent or more (4). Crop breeding can substantially increase grain yields by improving the plant's ability to partition the biomass it produces into grain. However, minimal research has been conducted on most of these crops to date, so much work remains and progress will be gradual. Since crops are grown for fodder and other purposes besides human consumption, these multiple objectives should be reflected in breeding priorities.

Rewards from breeding will be increased if they can be used as catalysts to bring about additional agricultural changes. Yield increases can begin a cycle of economic growth. For example, a crop yield increase from 600 to 800 kg/ha represents a 33-percent gain in productivity. But the farmer's profit may be doubled, tripled, or even increased tenfold, depending on the initial break-even point. Thus, the farmer has more income to purchase, among other items, additional inputs that will further increase yields, reduce drudgery, etc. When local entrepreneurs are stimulated to produce these inputs, such as small-scale machines, the development process is further enhanced.

Crop Breeding Cautions

Crop breeding often has resulted in replacing traditional landrace mixtures with pure lines of improved varieties. This practice can increase a crop's vulnerability to new epidemics and environmental stresses. First, since appropriate breeding emphasizes resistance to pests, improved varieties should be less susceptible to pest damage than original landraces. However, the ongoing co-evolution of pests and their host plants requires continued genetic input from traditional varieties to maintain the gains from breeding (39). A recent proposal calls for incorporating landraces and wild relatives of crops into development assistance efforts. Traditional cropping systems can be "modernized" while still serving an important role as crop germplasm repositories (2). Second, the risk of a disease or pest epidemic increases if the mixture of varieties planted in an area is replaced by any one variety, regardless of whether it is an "improved" one or not. Therefore, many varieties should be used rather than planting extensive areas with one genetic type.

Another caution to consider when introducing new varieties is that they should not adversely affect the biological equilibrium between the crop and pests and diseases. The first sorghum hybrids used in India carried no resistance to Striga, a major parasitic weed. Seeds from the weed are now much more abundant than they were traditionally, and they persist in the soil for 10 years. Striga generally is a more serious problem in Africa than Asia. Thus, the potential for a similar incident to occur through the careless release of a crop variety with insufficient resistance is greater in Africa (4).

Scientists conducting breeding efforts should try to anticipate the social effects of their work. The Green Revolution in Asia has been criticized for increasing existing social inequality. An evaluation of the Consultative Group on International Agricultural Research (CGIAR) system, however, disagreed, arguing that reductions in the price of grains favor the poor more than the rich who spend a smaller portion of their income on food. They go on to caution, however, that "technological advance, while vital for the development of agriculture and the economy, is a poor instrument for redistributing wealth" (27). Another social issue involves the need to understand demands on labor, including household division of labor. A critical issue in regard to the expansion of root crops, for instance, is the potential increased demands on women's labor. Since women have responsibility for producing and processing most of these crops, any expansion should also be accompanied by improved production techniques, improvements in extension and local processing facilities, and increased access to credit (52). The role of biotechnology in plant breeding may raise similar equity issues (box 9-2).

Problems and Approaches

Many non-technological factors that impinge on food production, such as the need for African governments to improve incentives for farmers to grow food, also apply to the issue of crop breeding. Markets for inputs and outputs need to be developed and stabilized wherever possible. Concerns are also expressed regarding the distortion of local tastes and demands that result when donors supply food aid in the form of crops that cannot be grown locally. OTA has identified several problems more specific to crop breeding.

1. Decreasing the Gaps Between On-station and On-farm Results

One of the most striking features of African agriculture is the small impact that improved varieties have had, despite the dramatic results achieved at experiment stations. On-station yields commonly are on the order of 40 to 60 percent greater than on-farm yields (31). Several activities could help reduce the gap between on-station and on-farm results:

- *Collect baseline data on present crop production levels and constraints*: Farming systems research (FSR) can ensure that breeding objectives are developed with farmer input, based on knowledge of the farming system in which the improved variety will be used, and that the varieties are viable when used under the conditions and constraints facing the farmer. FSR teams should evaluate improvements such as improved processing ability, not just yield increases, resulting from use of improved seed.
- *Include a mix of natural and social scientists on the research team*: It is particularly important that women be well-represented among researchers and extensionists. African women have primary responsibility for consumption decisions and, therefore, strongly influence the adoption of improved varieties.
- *Identify improved varieties that have performed well under similar agroecological and socioeconomic conditions*: These varieties from other continents or simply from other parts of Africa need to be extensively screened under local conditions.
- *Increase on-farm research and trials*: A proper balance is needed between creating appropriate genetic variability on the

Box 9-2.—Biotechnology's Impact on African Agriculture

Biotechnology includes a variety of methods for introducing and reproducing new genetic variation in organisms as well as a number of industrial applications of biological processes. Specific technologies related to plant breeding include tissue culture and other techniques for propagating plants; fusion of plant cells (protoplasts) either within or between species; and precise recombinations of DNA, the genetic material (53). These techniques could enable plant breeders to work faster, to adapt plants more precisely to specific situations, and to introduce new traits into crops either from other plants or from micro-organisms. In some cases, plant cell cultures could replace field-grown crops.

So far, certain types of biotechnology have moved rapidly into commercialization and are used in developing as well as developed countries. For example, some Kenyan farmers grow potatoes from materials provided by the National Plant Quarantine Station in Nairobi. These materials originated in tissue cultures sent from the International Potato Institute in Peru. Other, more complex biotechnologies have been slower to develop than expected. Significant impacts on plant agriculture are expected first in developed countries in 5 to 20 years (13,54).

The application of biotechnology to plant breeding in Africa continues to be small. Many methods rely on highly trained technicians and expensive laboratory equipment that is currently beyond the capacity of most African countries to purchase and maintain. Many plant breeders argue that African nations should draw on others' research results—especially those of the International Centers and the developed countries private sectors—rather than develop their own facilities. Enthusiastic support, including that of several African countries, for the new International Center for Genetic Engineering and Biotechnology suggests that developing countries prefer to develop their own capacity for biotechnology to a certain extent (37).

Plant breeding and other changes in African agriculture due to biotechnology are likely to be important in the long-term (13). Significant issues related to biotechnology's availability and use will have to be resolved, though. For example: Unlike many plant breeding improvements in the past, biotechnology is concentrated in the private, not public, sector of developed countries. How can interested countries ensure access to the benefits of this research. What long-term relationships with U.S. firms and/or universities might be possible? How might African governments and farmers derive greater benefits and incentives to maintain the valuable germplasm resources contained in the diverse genetic base of their agricultural and wild species? How can biotechnology's benefits be provided to resource-poor farmers and herders when they are not major consumers of its products, nor are they likely to have the skills, money, and market experience to take full advantage of new methods? Perhaps most importantly, how can African countries prepare for the possibility that major export crops such as pyrethrin and cocoa, and the livelihoods of the farmers who produce them, may be displaced by genetically engineered products in developed countries?

experiment station and adaptive research under on-farm conditions. Experiment stations allow for research under more controlled conditions, such as artificially high-pest pressures. On-farm trials increase the probability that new varieties will be useful under farmers' conditions and increase rates of adoption. Farmers' fields can also be used to preserve diverse genetic material.

2. Choosing Appropriate Breeding Priorities

The research agenda chosen by crop breeders can enhance this discipline's contribution to African food security. The new emphases on ensuring that improved varieties meet the objectives of resource-poor farmers and fit into their farming systems are particularly critical for Africa. A consensus is emerging on the ob-

Photo credit: Donald Plucknett/Consultative Group on International Agricultural Research

On-farm research is crucial to increasing the impact of improved varieties. In Rwanda, this farmer and scientist work together to test different crop combinations and various soil and water management schemes for growing cassava, plaintain, and maize.

jectives of genetic improvement programs that will most benefit resource-poor farmers and herders:

- **Varieties that are higher yielding under farmer conditions:** Researchers are paying more attention to developing varieties that produce a reliable yield under the variable, often adverse conditions of the farmer —and less emphasis on their ability to yield well under the ideal conditions created at the experimental station.
- **Yield stability:** An improved variety must be able to produce in bad years. This trait is a prerequisite to breeding efforts directed at maximizing yields under a range of environmental conditions.
- **Pest and disease resistance**: Protecting crops from pests and diseases can be one of the most effective means of increasing and stabilizing production.
- **Tolerance for environmental stress**: Breeding can improve crop tolerance for adverse environmental conditions, rather than requiring that the environment be modified.
- **Improved quality, storage, and ease of processing**: Criteria for improving quality include increased protein content and fewer toxic and anti-nutritional factors. Adoption of varieties will be enhanced by efforts to ensure that the harvest can be stored and processed to fit local consumption preferences.
- **Adaptation to diverse agricultural systems, reflecting the multiple uses of the products**: Improved varieties will be used more by resource-poor farmers if the improvements address their needs and fit their practices. For example, while the grain from cereals is used for human nutrition, the stalks are a valuable source of fodder, cooking fuel, and building material.

Even when an improved variety is shown to do well under farmers' conditions, a complex of factors influence adoption rates. For example, a newly developed sorghum hybrid (Hageen Durra I), released in Sudan, has generated excitement because it is capable of greatly increasing yields under experimental conditions. Although the hybrid yields less under resource-poor farmers' conditions, it still has been an important factor in raising production in Sudan. According to recent reports, however, it is suffering a serious setback. Now that food is more plentiful in some regions, farmers are returning to the traditional varieties because they are preferred for preparing a favored food, Kisra (30). Another factor in the shift is the inability of farmers to sell surplus sorghum at a price that justifies buying the more expensive hybrid (11). Even with improved varieties that the farmer does not have to buy each year, adoption rates are still low. Probably no more than 10 percent of the land in Africa devoted to cereal production is planted with improved varieties (49).

3. Matching Crop Research Funding With Importance for Food Security

Along with the shift in breeding priorities, there could be a redistribution of research funding so that attention to various crops would more closely reflect their respective contribution to the food security of the African people. The level of research that has been directed toward many African crops, particularly food crops, is low.

Table 9-2 presents rough estimates of research expenditures by commodity, expressed as a percentage of the value of production to the commodity. The data indicate that while certain export crops, such as coffee, cocoa, and sugar, have received substantial attention, food crops, particularly cassava and sweet potatoes, have been largely ignored, not only in Africa, but throughout the developing world. It is also notable that livestock have received considerably more attention in Africa, based on their relative economic value, than food crops (42).

Crop breeding research to improve food security should also direct specific attention to those crops most important to the resource-poor farmer, largely neglected to date. Only about 15 African scientists are concerned primarily with millet breeding on some 15 million hectares in about 12 African countries. About 100 breeders work on millet for roughly the same area in India. An acute need exists for all categories of scientists in Africa but it is not unrealistic to hope that 25 additional millet breeders could be trained by the year 2000 (4). In addition, the food legumes and the root crops, tubers, and plantains have been especially neglected. A key factor causing this neglect is the predominant subsistence use of these crops.

In the short term, operating funds could be increased for existing scientists. A supplement of $20,000 per year would enable a scientist to pay most operating costs (fuel and cultivation, consumable field and lab supplies), buy basic equipment, and provide and run simple seed storage operations (4).

4. Improving Seed Multiplication and Distribution

In order to achieve benefits of improved varietal development on a wide scale, African countries need to develop or gain access to viable seed industries. Currently, few African countries have adequate seed industries—public or private—that can handle, process, store, or market seeds. Moreover, few have mechanisms to test improved varieties in farmers' fields, or have adequate seed laws to encourage indigenous seed industries or promote private external investments (38,50).

Low seed multiplication capability is a major obstacle to wider use of improved varieties, especially maize, but also for millet, sorghum, and rice. Also, low multiplication rates or genetic purity problems exist in crops such as groundnut, cowpea, and cassava (3). As a result, farmers are unable to obtain improved varieties despite crop breeders' successes. Local seed production and distribution is preferred

Table 9-2.—Research Expenditure as Percentage of Product Value, by Commodity, for Selected Countries in Different Regions of the World (average of 1972-79 period)[a]

	Region				
Commodity	Africa[b]	Asia	Latin America	All countries[c]	International centers
Starchy Staples:					
Wheat[d]	1.30	0.32	1.04	0.51	0.02
Rice	1.05	0.21	0.41	0.25	0.02
Maize[e]	0.44	0.21	0.18	0.23	0.03
Cassava	0.09	0.06	0.19	0.11	0.02
Potatoes	0.21	0.19	0.43	0.29	0.08
Sweet potatoes	0.06	0.08	0.19	0.07	0.00
Field beans	1.65	0.08	0.60	0.32	0.04
Other Food Crops:					
Vegetables	1.56	0.41	1.13	0.73	0.00
Soybeans	23.59	2.33	0.68	1.06	0.00
Citrus	0.88	0.51	0.57	0.52	0.00
Export Crops:					
Cotton	0.23	0.17	0.23	0.21	0.00
Sugar	1.06	0.13	0.48	0.27	0.00
Cocoa	2.75	14.17	1.57	1.69	0.00
Bananas	0.27	0.20	0.64	0.27	0.00
Coffee	3.12	1.25	0.92	1.18	0.00
Groundnuts	0.57	0.12	0.60	0.25	0.005
Coconuts	0.07	0.03	0.10	0.04	0.00
Livestock:					
Beef	1.82	0.65	0.67	1.36	0.02
Pork	2.56	0.39	0.60	1.25	0.02
Poultry	1.99	0.32	1.12	1.64	0.00
Other livestock	1.81	0.89	0.42	0.71	0.00

NOTES:

[a] Data on research expenditures by commodity have to be estimated indirectly and are consequently very rough. Data may vary considerably according to different sources (42).

[b] Includes Egypt, Ghana, Kenya, Nigeria, Sudan, Tanzania, Tunisia, and Uganda.

[c] Twenty-six developing countries accounting for 90 percent of developing country agricultural research expenditures (excluding China).

[d] Most of the wheat research in Africa was carried out in North Africa.

[e] Includes millet and sorghum research for Africa.

SOURCE: M.A. Judd, J.K. Boyce, and R.E. Evenson, "Investing in Agricultural Supply," Economic Growth Center Discussion Paper No. 442 (New Haven, CT: Yale University, 1983. As calculated by John M. Staatz, "The Potential of Low-Resource Agriculture in African Development," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).

because of the need for local adaptation, but this may not be possible in many countries. Greater private sector efforts could be encouraged in this area but an obstacle is that few African nations have adequate seed laws to protect companies' investments (38).

The potential for promoting private seed companies is very uneven in Africa. For poorer countries where markets and infrastructure are weak, private investment is unlikely. In such cases reliance on public efforts and access to germplasm from international centers is most important. A few examples exist where countries have been successful in developing indigenous seed multiplication industries or have capitalized on the use of imported high-yielding varieties. In Sudan, a dozen local farmers/businessmen/entrepreneurs independently attempted to produce Hageen Durra I in 1985 and 1986, but it remains to be seen whether the effort is successful (3).

Some concerns have been expressed over undesirable consequences of seed laws that grant varietal patent protection needed to encourage private investments in developing countries. Cited adverse effects include negative impacts on research activities at international centers, establishing monopoly powers, and reducing germplasm diversity. There is disagreement over the existence or extent of such negative effects, but research shows that support for public plant breeding efforts (e.g., national and international research centers) help to counter them (55).

ANIMAL BREEDING

Although the donkey is the only major livestock species that originated in Africa, a diversity of animal breeds are now present there. Centuries of exposure to the wide range of environments and diverse management systems on the continent have allowed livestock to evolve and be actively selected to meet a range of needs. Some 50 varieties of cattle and similar numbers of goats and sheep have been identified (60). African livestock have been bred specifically to be able to cope with environmental stress and serve multiple uses. Not surprisingly, Africa's livestock tend to be late maturing, slow growing, and modest milk producers (6).

Although African livestock breeds generally are less productive than temperate breeds, they typically outperform them under the harsh environmental conditions and low-input management systems that exist in much of Africa. Therefore, little potential for genetic improvement to increase milk or meat production exists without reducing nutritional, disease, and climatic stress (6). Genetic improvement and use of exotic breeds will become more viable components of intensified systems as animal health, nutrition, and management are improved. Considerable potential exists to improve milk and meat production of ruminant breeds in certain favorable areas, specifically in highland regions. In lowland regions, environmental factors have led to management systems that typically provide little supplemental feed or health care, so the potential for production improvements is modest. Some potential exists, however, for genetic improvement in disease resistance.

The presence of tse-tse fly, which carries the disease trypanosomiasis, severely restricts cattle raising in about 40 percent of Africa. However, 5 percent of Africa's cattle, sheep, and goats display genetic resistance to the disease, so there is some opportunity for livestock breeding, evaluation, and selection programs to enhance this characteristic (see ch. 11).

Most livestock breeding programs in Africa have focused on cattle. Recently, small ruminants, and to a lesser extent camels, are being recognized as components of improved low-resource management systems. Breed improvement programs have stressed cross-breeding and introducing exotic breeds because these approaches provide visible and rapid gains in upgrading local stocks (23). However, few of these efforts have proven successful.

Resource-poor farmers and herders generally have not benefited from this emphasis on exotic cattle breeds. For poor rural people, exotic cattle are usually impossible or unattractive investments: they come in large valuable units which are not divisible while alive and which do not store well when dead. Only households already well buffered against contingencies can risk capital on exotic cattle. In contrast, the animals usually owned by poor rural people are cheaper and smaller. They may be native cattle, somewhat resistant to local diseases, or other species of animals (8).

While crossbreeding with exotic breeds and development of composite breeds (where environmental conditions allow) can enhance performance, recent research shows indigenous livestock to be more efficient producers than previously thought, thus warranting further investigation (60). Concern exists, however, that the lack of national breeding policies and the prevalence of indiscriminate crossbreeding programs are currently threatening a number of these potentially useful, indigenous livestock breeds with extinction (1,23).

The Potential of Specific African Animals

Cattle

African breeds of cattle fall into three main groups—the humped Zebu in the north, the humpless or taurine breeds that predominate in the tsetse fly-infested humid and sub-humid zones, and the small cervico-thoracic-humped Sanga common in the southern and eastern Savannah regions (6). Compared to temperate breeds, the potential to increase weight or milk production through genetic manipulation is generally low in these breeds (12). Because of these limitations, efforts to meet increased demands for livestock production, particularly cattle, have focused on crossbreeding and introducing exotic breeds. These breeds also fall under three basic groupings—Zebus (e.g., Sahiwal and Brahman types) from Asia and America, European beef and dairy breeds, and exotic Zebu/European hybrids such as the Bonsmara and Santa Gertrudis (6,44).

Despite considerable research on breed improvement in virtually every country in Africa, during colonial and post-independence periods, only some 3 percent of Africa's cattle herd has been affected (60). Most of this small improvement has occurred on cattle ranches and small dairy farms in a few select countries (e.g., Kenya and Malawi) (50). Surprisingly, little is known about the comparative performance of the various breeds (6). A review of some 500 papers on livestock research published between 1949 and 1978 show that only one-fifth have any comparative data and only one-quarter had data that enabled direct quantitative comparison (i.e., based on some common productivity index) (45).

Notwithstanding this poor track record and paucity of data, a few success stories exist. The case of development of dairy farming in Kenya is perhaps the most notable (21). In certain highland regions in Kenya, the use of cows crossbred between local and European dairy breeds has brought sixfold increases in milk yields. The number of these crossbred cows has increased significantly, averaging 14 percent per year between 1960 and 1975. Kenya Cooperative Creameries has emerged as a successful dairy enterprise supplied by a network of some 300 smallholder cooperatives. The success of this enterprise is attributed to: favorable climate, good infrastructure and markets, and support from government and extension services. Further increases may be possible in other highland regions with similar favorable conditions. For example, preliminary efforts to intensify milk production in the Ethiopian highlands seem promising (33).

Less dramatic, though more widespread, benefits may result from cross-breeding with breeds more suited to tropical conditions. For example, Sahiwal cattle from Pakistan were first introduced into Kenya almost 50 years ago and have since become a significant breed in some semi-arid regions (1). For much of Africa, however, the potential value of introduced breeds is small. As one assessment of prospects for breed improvement and conservation in the Sudan reported (36):

> [A]ny genetic improvement programme, involving crossbreeding or importation of purebred European cattle to the country for replacement of indigenous cattle, is not only impracticable but also undesirable. The use of exotic stock is at best a restricted activity in certain farms that can afford provision of improved feeding and management conditions not at present available in small farms and nomadic/trans-humant herds.

A need to focus increased attention on indigenous breeds is evident. However, many governments continue to emphasize crossbreeding and introduction programs despite a poor record of genetic improvement to date, and despite a basic lack of knowledge about breeds appropriate to the region (60). It is becoming increasingly clear, however, that priority in breeding activities should be shifted to emphasize local stocks, particularly gathering and evaluating field data to establish their merits, limitations, and potential for improvement.

Photo credit: Donald Plucknett/Consultative Group on International Agricultural Research

Gambian N'dama cattle are typical of several indigenous African breeds—they possess valuable genetic traits (in this case, tolerance to trypanosomiasis, a widespread disease).

A related priority for African livestock development is to take action to avoid extinction of various African breeds. Some efforts already have been launched, but potentially valuable genotypes continue to be threatened for a variety of reasons (table 9-3). There is a need for additional national and international breed conservation efforts (23,55).

Small Ruminants and Camels

Just as the so-called "poor peoples crops" (e.g., roots and tubers) have been largely overlooked in crop research, small ruminants (e.g., sheep and goats) and camels have suffered similar neglect despite their important role in providing animal protein in African diets. Interest in these animals is increasing, however. Within the last few years, for example, the International Livestock Center for Africa has organized a Small Ruminant and Camel Group to identify, disseminate, and promote research. Also promising is the work of the Small Ruminant Collaborative Research Support Program (SR-CRSP) in Kenya, particularly its emphasis on training African scientists in small livestock research.

Research from the Small Ruminant and Camel Group suggests that the reproductive performance of small ruminants within traditional production systems can be improved (26). Increased attention should be directed toward deemphasizing breeding controls that limit lambing or kidding to once a year because evidence exists that non-seasonal breeding among indigenous breeds can provide higher reproductive output. To optimize annual reproductive rates, livestock breeders may want to manipulate intervals between birthings, average age of breeding females, as well as litter size (26). Improved reproductive performance has also been obtained from camels as a result of improved management and nutrition—reducing intervals between births from 26 to 18 months. These improvements reinforce the notion that better animal husbandry holds more immediate potential than genetic improvements.

Disease aggravated by poor nutrition is the major constraint on small ruminant production

Table 9-3.—Endangered African Cattle Breeds

Breed	Location	Main use	Reasons for decline in number	Traits that justify conservation
Maturu	Nigeria	Meat, draft	Crossbreeding; lack of interest by farmers as tractors become available; Nigerian civil war	Trypanotolerant;[1] hardy; good draft animal; low mortality; short calving interval
Lagune	Benin, Ivory Coast	Meat	Crossbreeding; lack of interest by farmers because of small mature size (125 kg) and low milk yields	Trypanotolerant; adapted to humid environment
Mpwapwa	Tanzania	Milk, meat	Lack of sustained effort to develop and maintain breed	Adapted to semi-arid plateau of central Tanzania
Baria	Madagascar	Milk, meat	Crossbreeding	Adapted to local environment; humpless
Creole	Mauritius	Milk, meat, draft	Crossbreeding	Adapted to local environment
Kuri	Chad; Nigeria	Milk, meat	Numbers greatly reduced by rinderpest and drought; political instability	High milk production potential; able to swim long distance; tolerant of heat and humidity
Kenana	Sudan	Milk,	Crossbreeding; loss of major habitat to development scheme	Good dairy animal; adapted to hot, dry environment
Butana	Sudan	Milk	Crossbreeding	Good dairy animal; adapted to hot, semi-arid environment
N'Dama	Gambia, Senegal, Guinea	Meat	Crossbreeding	Trypanotolerant; efficient meat producer under poor conditions

[1] Ability to survive Trypanosome infection (spread by tse-tse fly) that causes African sleeping sickness in cattle.

SOURCES: K.O. Adeniji, "Recommendations for Specific Breeds and Species for Conservation by Management and Preferred Techniques," U.N. Food and Agriculture Organization, *Animal Genetic Resource Conservation by Management, Data Banks, and Training*, FAO Animal Production and Health Paper No. 41 (Rome: FAO, 1984); pp. 89-98 and R. McDowell, Visiting Professor, Department of Animal Science, North Carolina State University, Raleigh, NC, personal communication, 1987.

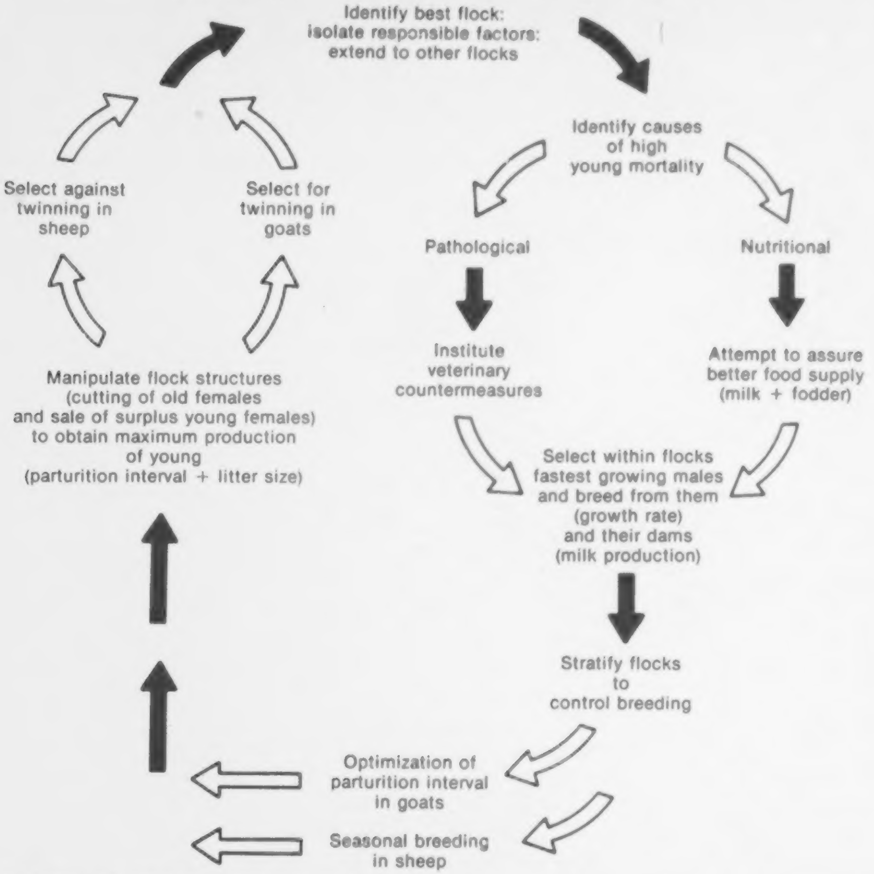
(57). Breed improvement and selection is thus important primarily as a component of improved management systems. An integrated research approach to developing improved production systems would have to consider a variety of needs. For instance, in a project to enhance goat milk and meat production, crossbreeding and upgrading indigenous breeds were done in conjunction with improving nutrition and management (58). Preliminary evaluations suggest that low-cost improvements could double production beyond that of using large ruminants (24). Although most research is focused on areas where the environment is favorable, improvements are also possible in less accommodating environments (46).

Research on small ruminants in Africa has shown consistently large variation in output among different flocks of sheep and goats within various regions—as much as fivefold differences between the best and worst flocks (57). These differences are principally a function of individual management. This suggests that significant increases in productivity and improvements to human welfare can likely be achieved by low-technology, low-cost packages based on improving existing management practices and existing biological potential within traditional systems already found in Africa (57). Figure 9-1 outlines, in general terms, a set of "improvement pathways" based on the best features of an existing pastoral system in Kenya.

Poultry and Swine

Poultry production is ubiquitous in Africa, but the intensity of production varies greatly. By far the most prevalent is the traditional scavenging system using local breeds and little supplementary feed, water, or veterinary care (50). Since the threat of a disease that can quickly wipe out entire flocks is ever present, farmers are discouraged from maintaining large numbers of fowl or investing much in supplementary care. However, research on progressive intensification of traditional, low-input management systems suggests that major increases in production would be possible given access to adequate health services (table 9-4). Use of improved or introduced breeds may be important only in the latter phases of inten-

Figure 9-1.—Potential Improvement Pathways for Traditionally Managed Small Ruminant Flocks on Maasai Group Ranches


Identify best flock:
isolate responsible factors:
extend to other flocks
Identify causes of high young mortality
Pathological
Nutritional
Institute veterinary countermeasures
Attempt to assure better food supply (milk + fodder)
Select within flocks fastest growing males and breed from them (growth rate) and their dams (milk production)
Stratify flocks to control breeding
Optimization of parturition interval in goats
Seasonal breeding in sheep
Manipulate flock structures (cutting of old females and sale of surplus young females) to obtain maximum production of young (parturition interval + litter size)
Select against twinning in sheep
Select for twinning in goats

NOTE: Open arrows indicate alternative or secondary pathways.

SOURCE: R. Trevor Wilson, "Goats and Sheep in the Traditional Livestock Production Systems in Semi-Arid Northern Africa: Their Importance, Productivity and Constraints on Production," *Livestock Development in Sub-Saharan Africa: Constraints, Prospects, Policy*, J. Simpson and P. Evanelou (eds.) (Boulder: CO, Westview Press, 1984).

sification. Research on marketing strategies, in support of such increases in production potential, would also be necessary.

Swine production is a relatively minor component of livestock production in Africa, concentrated primarily in West African coastal areas. Breeds are nondescript Iberian types introduced by the Spanish and Portuguese, well adapted to scavenging production systems and resistant to many diseases (50). Some improved breeds (e.g., Large White) have been introduced subsequently, and productivity increases have resulted from improved management and feeding (e.g., with manioc, bananas, and oilseed cakes). African swine tend to carry a number of diseases and parasites transmissible to humans and, thus, intensive management in close proximity to humans may present health problems.

It is likely that most gains in pig production in Africa, derived from use of exotic breeds, will occur as a result of large-scale Western production technologies located near urban centers where demand exists. Swine production, as well as poultry production, represent perhaps the only examples where direct introduction of large-scale livestock production technology has proven widely successful.

Table 9-4.—Poultry Productivity Under Different Management Systems

		Outputs		
System	Characteristics	Eggs hen/yr	1 yr. old chicks/hen	Eggs for consumption
Traditional	Scavenging; no water, feed; inadequate night shelter.	20-30	2-3	0
Improved traditional Step 1	Regular water and grain; improve night shelter; care of hen/chicks in first week; Newcastle vaccination.	40-60	4-8	0
Improved traditional Step 2	Same as Step 1 plus further improvement in feeding, watering, and housing. Treatment for ecto- and endoparasites. Additional vaccination as indicated.	approx. 100	10-12	30-50
Improved traditional Step 3 (semi-intensive)	As Step 2 but with improved breeds; complete diet; hatching by local hens.	160-180	25-30	50-60

SOURCE: U.N. Food and Agriculture Organization, *African Agriculture: The Next 25 Years: Annex III Raising Productivity* (Rome: 1986).

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Chapter 10

Improved Use of Animals

CONTENTS

Page

Summary 237

Opportunities for Improved Use of Animals 243

Mixed Crop/Livestock Systems Using Small Ruminants 243

Animal Traction 245

Aquaculture 248

Potential 250

Problems and Approaches 251

Chapter 10 References 252

Boxes

Box *Page*

10-1. Contribution of Livestock to Agricultural Development 238

10-2. Pastoralism in Africa 239

10-3. Fisheries Development in Sub-Saharan Africa .241

10-4. Two New Farming Systems Using Small Ruminants 244

10-5. Elements of Successful Aquaculture Development in Zaire 249

Table

Table *Page*

10-1. Livestock Distribution by Farming System in Sub-Saharan Africa 238

Chapter 10

Improved Use of Animals

SUMMARY

Animals figure prominently in African economies, representing an estimated $10 billion in annual production of livestock products and services. An additional $3 billion is derived from fishing (40). Numbers of cattle and goats per person are considerably higher for Africa than the world average, although production per animal (as well as for sheep, poultry, and swine) is significantly lower (40).

African livestock serve a variety of important functions beyond producing meat and milk, although the latter typically is of primary importance (box 10-1). Also, animals are raised in a variety of ways:

- about three-quarters of Africa's livestock are raised on small farms where crops are the principal source of subsistence, and animals provide a major source of cash income;
- only 6 percent are reared on commercial ranches (table 10-1); and
- another 20 percent are herded in pastoralist systems where livestock provide the major source of both food and income.

The estimated 16 million African pastoralists have developed a number of specialized technical and social responses to deal with an inherently risky livelihood. Studies show that African pastoralist systems use scarce resources effectively. Although production per animal is low by normal world standards, African pastoral systems are generally more productive than ranching systems in Africa, Australia, or the United States when measured by other criteria, including food production per unit of land (2). Nonetheless, these systems are not self-sufficient in food production and depend to a significant degree on market links to buy food from farmers. Nomads, for example typically derive about one-half of their diet from milk, 16 percent from meat, and 34 percent from purchased cereals and other food (49).

Helping pastoralists presents unique challenges for development assistance because of pastoralists' mobility, their harsh and unpredictable environment, and their relative isolation from national economies (box 10-2). Any improvements in productivity are bound to be marginal. The primary potential of technologies to support pastoralist systems lies in the improved veterinary support and animal nutrition that are examined in chapter 11. This chapter focuses on the mixed crop and livestock systems that account for most African livestock production. The practices discussed—integrated crop/livestock systems using small ruminants and improvements in animal traction and aquaculture—can enhance the contributions that animals within farming systems make to resource-poor agriculturalists.

Major issues in African low-resource fisheries development are briefly outlined in box 10-3. OTA's analysis of fish production technology, however, is restricted to aquaculture development (this chapter) and technologies to reduce post-harvest losses of fish (ch. 11). Technologies for marine and inland fisheries development are not considered here. However, an analysis of various marine and inland fisheries technologies for developing countries is the subject of a recent report by the Board on Science and Technology for International Development (35).

Aquaculture—or fish farming—is not a common tradition in Africa, and represents only a fraction of Africa's total fish catch. Nonetheless, aquaculture holds particular promise for

Box 10-1.—Contribution of Livestock to Agricultural Development

Livestock, particularly in the farming systems context, provide many other benefits in addition to food. Food may not necessarily be the greatest concern for resource-poor farmers and herders. Development efforts in the past have usually been aimed at the improvement of livestock productivity for meat, however.

Animal Traction.—Livestock are a major supplier of draft power in the third world. Livestock provide an estimated 75 percent of traction power—ranging from a low of about 10 percent for Africa to as high as 99 percent for India. The use of animal traction will continue to be of importance to low-resource agriculturalists due to the high cost of fossil fuel and mechanical equipment and the ability of draft animals to use low-quality crop residues for their subsistence.

Food Reserve.—The food reserve or insurance against crop failure provided by livestock is important, particularly in those areas where climatic variation causes frequent fluctuations in crop production. During droughts, animals provide food, while during good years the herds are increased. Although herds will fluctuate in size they provide security from climatic-induced crop failure. Usually enough of the herd will survive poor years so that the size can increase when climate improves.

Capital Accumulation.—Livestock serve as a bank which can be converted to cash as needed. The fund can be used for emergencies and medical expenses, school costs, taxes, and making investments in agricultural resources. Draft animals are often rented as a source of family income.

Value-Added.—Livestock convert low-value household and community-owned forage and family-supplied labor into high-value products. In extensive grazing systems, cattle, sheep, and goats graze on land which has no value for crop production. In intensive, confined systems (pen feeding) small ruminants are fed low-value crop residue and hand-collected forage harvested from land unsuitable for normal crop production. Children and women provide labor for these enterprises thus adding to family income and food supply.

Manure.—Most animal manure is valued as a source of fertilizer for crop production, and some types are used as building material and/or as a source of cooking fuel. As a source of fuel, manure reduces the pressure upon forest resources which are severely depleted in many parts of Africa. But its fertilizer benefits are lost when burned.

Social Equity.—Because land is not equitably distributed, development of crop agriculture has not benefited the landless. Ownership of small livestock may not require land ownership because of availability of public land or the development of backyard intensive projects. Animals provide opportunity for food and income for the landless. Because livestock products are purchased by urban people who have wealth, they will provide a channel for income to the poor.

Export Earnings.—Livestock products are a potential source of foreign exchange. Many African countries produce meat, hides, and fiber in excess of domestic needs and export provides important foreign exchange for the domestic economy.

SOURCES: Robert E. McDowell, *Ruminant Products: More Than Meat and Milk* (Morrilton, AR: Winrock International Livestock Research and Training Center, 1977); R.W. Rice, "Domestic Livestock in Arid Lands FSR/E," Department of Animal Science, University of Arizona, unpublished manuscript, n.d.

Table 10-1.—Livestock Distribution by Farming System in Sub-Saharan Africa

	Livestock units ($\times 10^6$)	Percent
Ranching	8	6
Pure pastoralism	29	20
Pure mixed farming	32	23
Agropastoral[a]	74	51

[a] Classification reflects the large number of animals that use communal lands for part of the year and farm land for the remainder.

SOURCE: P.J. Brumby and J.C.M. Trail, "Animal Breeding and Productivity Studies in Africa," *ILCA Bulletin*, No. 23, January 1986, pp. 23-27.

increasing food security among many African resource-poor farmers. Promoting aquaculture, however, is a long-term undertaking requiring a prolonged period of technical support. Contributions and adoption are likely to be slow and incremental. Current efforts should be directed toward promoting extensive aquaculture systems, allowing systems to evolve into more intensive polyculture systems as expertise and availability of

Box 10-2.—Pastoralism in Africa

An estimated 6.8 million people in West Africa, south of the Sahara, and 9.3 million people in eastern and southern Africa depend on pastoral herding as their principal livelihood (30). Three general categories of pastoralist production are (9,49):

- **Nomadism**: Pastoral systems almost entirely dependent on livestock and that do not involve a permanent place of residence or practice of regular cultivation.
- **Transhumant Pastoralism**: Pastoralist maintains a permanent residence for several years near which a few crops are typically cultivated. Animals are usually herded by adult male members of the household, sometimes migrating over hundreds of kilometers, in order to obtain adequate forage and water.
- **Sedentary Pastoralism**: A form of mixed farming where permanent residence is established and crops are grown, but livestock production is the dominant enterprise.

These three forms of pastoralist production have been described as "three different ways of life (that) are specific human answers to the painful choice between high-quality forage and drinking water" (2). This characterization stresses the importance of water and soil nutrients in determining the form of livestock production in the arid and semi-arid Africa where pastoralism prevails. Water is the limiting factor in the driest region (i.e., below 300 mm rainfall). In these low rainfall areas, the growing season may only last 1 month but the vegetation produced is nutrient rich. Nomads and transhumant pastoralists try to take full advantage. Availability of soil nutrients quickly replaces water as the limiting factor in wetter regions. The increased quantity of available forage in the wetter regions cannot compensate for poor nutritional quality of forage due to inadequate availability of nitrogen (as well as reduced digestibility and phosphorus content) (2).

Researchers have also identified a wide array of adaptive strategies employed by pastoralists to ensure reliable and adequate production throughout the year in their unpredictable and unproductive environment (7,8). Briefly, these include:

- **Movement**: Movement is an obvious but essential aspect of pastoralist production that enables herders to take optimal advantage of patchy, fluctuating, and low-density resources. Pastoralists also tend to divide herds into smaller groups to further optimize use of scarce resources.
- **Use of Resource Reservoirs**: Pastoralists depend on pockets of higher biotic productivity (e.g., highlands, swamps, or rivers), as forage and water availability in the broader range become scarce—either seasonally or because of poor rainfall. Social mechanisms commonly evolve to help control use of these resources. Because of their greater agronomic potential, these areas also tend to be the focal points of farmer encroachment or other agricultural development schemes that can undermine this critical resource for pastoralists.
- **Species Composition and Herd Structure**: Multi-species herd composition provides effective use of available browse as well as providing pastoralists with consistent supply of food due to differing periodicities of growth and reproduction, and differing lactation patterns. Mix of different species is also a function of plant productivity and rainfall (e.g., higher proportion of cattle in more favorable areas or years). Herd size is typically maximized to the limits of available labor, while composition of household labor (i.e., age and sex) may also define herd structure.
- **Social Systems and Interactions**: These include the various ritual, political, juridical, and economic relationships that have developed to enhance efficiency in the use of resources and to provide insurance against disaster. Examples include various forms of resource sharing and redistribution.

Disturbing trends in land use and livestock ownership have emerged in Africa that raise serious concerns for efforts to promote food security among Africa's herders. Taken together they suggest a growing vulnerability to drought and famine among increasing numbers of poor pastoralists that depend primarily on their livestock for food and income.

First, pastoralists are among the biggest losers in Africa's growing competition for agricultural land. Poor farmers continue to expand into new areas due to population growth or displacement after giving up land to commercial production. Many have moved onto grazing land traditionally used by pastoralists. This, in turn, has forced pastoralists onto still poorer land. In addition to reducing productivity and increasing vulnerability of production to drought, this trend has resulted in a shift from what was largely a complementary relationship between farmers and herders to one of increasing conflict over resources (13,18,28).

Second, a marked trend toward increased economic differentiation is occurring in pastoralist communities. Specifically, ownership of herds is being heavily concentrated among a few wealthy stock owners and increasing numbers of pastoralists are becoming paid laborers to herd for these, often absentee, owners. Although this trend raises specific equity concerns, it also raises concern over sustainability in emerging systems (18,49).

> The intensity and specifics of absentee herd ownership vary but its occurrence has important implications for local ecology, since this group of "part-time" pastoralists usually operates outside the indigenous management system, and is likely to be less concerned than local herders with long-term conservation and grazing control (28).

Technical or institutional success stories in assisting Africa's pastoralists are rare. Not surprisingly, a high degree of frustration has emerged over the little progress that has been made in improving pastoralist production despite considerable investment. The fallout seems to be a retrenchment of development assistance effort in support of pastoralists. The argument made is that development funding is better spent where chances of success are more likely. In neglecting the development needs of this group, however, human impoverishment and land degradation are likely to accelerate. This dilemma has led to serious reevaluation among livestock and pastoralist development experts of where and how things have gone wrong, but questions of how best to proceed remain unresolved (12,45).

Some potential does exist for enhancing pastoralist livelihoods and improving their food security, but exploiting it may require a different approach and different expectations than have been applied to date. A growing consensus is emerging that development goals should shift more toward enhancing the subsistence base of pastoralist production sytems, rather than focusing on increasing meat production for commercial markets. Increased attention should be directed at smaller scale interventions and incremental improvements, rather than large-scale interventions. Also, failure to improve significantly on traditional production systems should be seen as testament to their effectiveness and suggests that building off existing systems—rather than replacing them—and tapping the knowledge base of pastoralists themselves is a rational approach to finding solutions (11).

Too often development efforts have focused on introducing a specific technology without assessing its broader impact on the larger production system or its desirability from the perspective of the pastoralists themselves. Greater appreciation now exists of the critical role of social and institutional devices that enable the direct participation of pastoralists in the definition, design, and management of projects (13,27). The emergence and support of local groups such as pastoralist associations is seen as a response to the needs for pastoralists to gain a greater voice in regional planning and political decisions affecting them. They also provide institutional mechanisms to assist herders in stemming the tide of expansion of sedentary farmers onto critical dry-season grazing areas. Such issues also relate directly to the need to address changing patterns of land tenure and communal resource use (46).

needed inputs and markets grow. Immediate gains in enhancing Africa's fisheries sector are possible through various technologies that cut down on post-harvest losses and spoilage (ch. 11).

Animal production can serve as an important catalyst to agricultural development among resource-poor farmers (31). Selling animals and their products commonly is the most important source of cash income for resource-poor farmers. This income can in turn be used to purchase inputs (e.g., fertilizer and improved seeds) to enhance crop production. National production statistics provide evidence of this positive association between livestock and crop

Box 10-3.—Fisheries Development in Sub-Saharan Africa

Fish, on average, provide about 12 percent of animal-derived protein in the African diet, three times as high as in Latin America and four times as high as in the Near East. Sub-Saharan Africa's approximately 2.7 million metric ton fish catch in 1984 was derived in almost equal parts from marine and inland fisheries (43). Africa's marine fisheries production declined between 1976 and 1984, while inland fishery production has increased about 8 percent during the same period. While large-scale marine fisheries have increased in importance in a few African countries, traditional small-scale (or artisanal) fishing still accounts for 85 to 95 percent of Africa's total fish catch (9,35,43).

Further development of Africa's predominantly small-scale fisheries faces many of the same problems as efforts to enhance low-resource farming and herding. Factors intrinsic to fishing operations, including low productivity and consequent low incomes, make investments in improvements difficult. Productivity is also hampered by the fishers' poor access to markets, transportation, and credit. A recent study of technologies for low-resource fisheries suggests that the most effective technologies are generally those that: 1) are adaptable to solving specific local problems, 2) mitigate against ecological or social disruptions, and 3) are economically feasible and desired by the community they are intended to serve. The study also concludes that projects promoting new mechanical or fabrication technologies should include a training component, service support, and emphasize locally available components and spare parts (35).

Productivity of traditional fisheries is being undermined by deteriorating natural resources. Overfishing and disruption (e.g., pollution) of spawning or feeding areas, commonly due to impacts of large-scale commercial operations, are major causes of this deterioration. Deforestation in coastal areas has also made certain woods that are preferred for boat construction increasingly scarce (35).

Just as low-resource farmers and herders have been largely neglected by national and international agricultural research, so too have the low-resource fishers been neglected. For example, studies show that although some 70 percent of the marine catch off West Africa is taken by small-scale fishers, this group receives no more than 20 percent of government fisheries funding. Considerable benefits are identified in supporting these small-scale fisheries, including creating employment, effective use of local investment, and production of high-quality products using little energy and causing little pollution (42). Evaluation of the economics of large- v. small-scale fishing in Africa is scant (9). One such comparative study for Sierra Leone, however, concluded that small-scale operations were more profitable and could produce fish at a lower cost per ton than large-scale firms (26).

The Fishery Committee for the Eastern Central Atlantic, a regional fishery organization set up by the U.N. Food and Agriculture Organization, has suggested numerous mechanisms to promote and protect African small-scale fisheries. Designating in-shore areas specifically for use by low-resource fishers, as has been done in Cameroon, Mauritania, and Senegal, is one mechanism. Developing credit for fishers to purchase canoes, nets, and motors is another. Interventions must be preceded by assessments of possible negative impacts on communities, however (42).

The neglected role of women should be integral to such investigation (24). Though they seldom go out in the boats, women play a critical role in shore-based fishing (e.g., 95 percent of the work-force in Ghana and Togo)—with principal responsibility for processing, transportation, and marketing. Further, women commonly are major owners and investors in boats and gear, the principal source of wealth among low-resource fishers (9,42).

production on small farms: generally speaking, those African countries with the greatest increase in stock numbers also experienced the highest cereal production increases (5).

Diversified production systems that include livestock (or fish) and crops also offer increased security of production. For example, producing millet as the staple grain in the northern Sahel is only possible because of the added food security provided by livestock rearing since millet crops often fail (49). Combining several types of livestock—for instance, cattle, goats, and sheep—further reduces vulnerability, provides a more consistent food supply, and can make more efficient use of available forage. Aquaculture has also been identified as a means to provide the rural poor with supplemental year-round food, even in many marginal areas (34).

Another element in the interrelationship between crops and animals is that crop residues are often a critical source of animal feed in low-resource agricultural systems. Pastoralists commonly establish reciprocal relationships with farmers so they can gain access to post-harvest fodder. The farmers benefit from the manure deposited in their fields or other remuneration such as milk or cash (28). Cattle in semi-arid and sub-humid zones of West Africa spend about 40 percent of their time feeding on crop residues, and these residues account for nearly half of their annual feed (31). This use of crop residues as fodder has important implications for crop breeding strategies.

Africans typically are large consumers of milk and sub-Saharan Africa has a rapidly enlarging deficit in milk self-sufficiency. At least 3 million tons are imported into the region each year commercially and through food aid (32). In light of the high demand for milk in Africa, increased attention should be directed toward better systems for producing, processing, and marketing milk. Potential is high to increase production under small farm conditions, but improvements in transportation and infrastructure, and other incentives will be needed (32).

Although most African farmers raise crops and livestock, these activities are seldom integrated well enough to make use of the full potential of mixed systems. In other developing regions, particularly in Asia, the complementary benefits provided by integrated crop/livestock production have been developed to a much greater degree. Integration in Africa has only occurred to any significant extent in the tropical highlands, where population pressure, scarce resources, and sparse land availability has motivated more intensified management systems. Livestock generally receive minimal management in most of Africa, mostly roaming free and scavenging for much of their food. Crop residues, household food scraps, and backdoor garden residues all provide feed supplements. However, growing crops and rearing livestock for the most part are separate activities.

Livestock rearing is undertaken as a secondary activity to crop production in most of Africa's mixed systems. Consequently, when labor, land, and capital are serious constraints, as is the case for resource-poor farmers, crops take precedence over animals. This helps explain why livestock generally receive little supplemental nutrition and health care, as well as minimal management. Providing resource-poor farmers with options to enable them to invest additional resources in their livestock is a major challenge to developing more productive crop/livestock systems. Integrating livestock into alley cropping systems and establishing small but intensive fodder gardens are two promising avenues being promoted by the International Livestock Center for Africa (ILCA) and some national governments (36). Initial results from work by the Small Ruminant Collaborative Research Support Program, supported by the Agency for International Development (AID), are also providing promising results in this area (48).

Food production for many resource-poor farmers, particularly in semi-arid and sub-humid zones, suffers from insufficient or untimely access to animal power to plow fields (37). Planting may be delayed and yields consequently decreased in cases where draft animals need to be leased or borrowed (16). The ability and willingness of resource-poor farmers to invest increased labor and other resources into managing draft animals might be enhanced where animals can serve multiple uses—sowing, weeding, harvesting, and transportation (49). To accomplish this, animal traction equipment needs to be designed in appropriate scale and affordable types. This must accommodate the smaller African oxen, and use equipment that can be produced and repaired locally (49).

OPPORTUNITIES FOR IMPROVED USE OF ANIMALS

Mixed Crop/Livestock Systems Using Small Ruminants

Small ruminants—sheep and goats—are a valuable asset for resource-poor farmers. They are generally well suited to small mixed farms because of the low capital investment per head, contributions to nutrition and family income (in small but timely amounts), and minimal competition for land and labor (47). Research on their actual contributions is scarce, however. Increasing attention now is turning to the complementary roles small ruminants can play in integrated crop/livestock systems, particularly in medium to high rainfall areas.

Rearing of small ruminants in mixed production systems often is a minor enterprise relative to crop production. For example, African women primarily engaged in food preparation and processing may complement these activities by rearing small numbers of animals using household wastes as feed supplements. Production efficiency could be improved, however, by taking greater advantage of possible complementary interactions between small ruminant and crop production (17).

- Small livestock are able to convert low-value crop residues to high-value animal products (e.g., milk and milk products, meat, hides, etc.).
- Animal manure provides an effective means to convert forage to fertilizer, particularly for small home garden plots.
- Rotations or intercropping of food crops with forage crops (especially leguminous species) enable farmers to produce high-quality animal feed, as well as increase soil fertility and control crop disease.

ILCA has been testing ways to enhance efficiency in low-resource farming systems by increasing crop/livestock integration in existing farm enterprises (see box 10-4). Two general approaches have emerged. One is an integrated alley farming approach based on work conducted at the International Institute of Tropical Agriculture in Nigeria, which links crops and livestock through the use of leguminous browse trees (ch. 8). The second is referred to as an Intensive Feed Garden Approach and is directed toward regions where land is scarce and animal confinement is appropriate or necessary (36).

Both systems are based on the premise that small ruminant production must occur within the context of existing agricultural systems. Researchers thus have stressed the need to keep demands for cash, time, and management to a minimum, as well as focusing attention on those areas where land scarcity makes increased management more acceptable.

Although research on both systems is incomplete, preliminary results are promising. As Africa becomes increasingly populated and livestock grazing is restricted in some areas, livestock production will have available more labor but less land. Efforts like the two ILCA models will become increasingly attractive to and necessary for resource-poor farmers, especially as greater confinement of animals increases the need for "cut-and-carry" fodder operations.

On-farm investigations of alley farms in Nigeria show greater flexibility in how farmers use the system than had been anticipated by researchers (36). This suggests that alley farming is adaptable to meet a variety of objectives under low-resource conditions and that tradeoffs in inputs are possible, enabling farmers to adjust systems to meet their particular needs or limitations. The Nigerian government has now initiated its own program to promote alley farming.

The intensive feed gardens have not been thoroughly evaluated. However, some investigations have shown that when the fodder crops are rotated to food crops after 2-year intervals, the enhanced soil nitrogen and organic matter can boost sorghum yields up to 300 percent (32). The system could offer a sustainable rotation that would be highly beneficial to low-resource farmers (32)—particularly under conditions where alley farming may not be possible, where

Box 10-4.—Two New Farming Systems Using Small Ruminants

Alley Farming in Humid Nigeria

Throughout much of the humid zone of West Africa, small ruminants are kept in free-roaming village flocks with low management inputs and relatively low productivity. ILCA's Humid Zone Programme has developed for this region an improved sheep and goat production system that is closely integrated with crop production.

The new system employs the fast-growing leguminous trees *Leucaena leucocephala* and *Gliricidia sepium* as animal feed and as a means of maintaining soil fertility. The system uses alley cropping techniques in which crops are grown in 4-m wide alleys between rows of *Leucaena* or *Gliricidia*. During cropping years, 75 percent of the tree foliage is applied to the soil as mulch, while the rest is fed to small ruminants. The cropping system is periodically fallowed for 2 to 3 years, and during this period the natural vegetation, as well as the tree foliage, is eaten by small ruminants.

The Humid Zone Programme is evaluating 16 alley farms in different villages. All farmers include *Leucaena* and *Gliricidia* trees that have been established from seed. At least 40 accessions of *Gliricidia* were collected from Costa Rica during 1983, some of which are now producing fresh weight yields 160 percent higher than the local types.

Nigeria's Federal Livestock Department is starting a pilot development project in which 60 participating farmers will practice alley farming on their own land. The farmers will also adopt an improved animal health package recommended by ILCA, which includes vaccination and dipping to prevent common diseases.

Fodder Banks in the Subhumid Zone

Livestock producers in the West African subhumid zone have great difficulty feeding their animals during the long dry season. Fodder is scarce and of poor quality, and cattle commonly lose 15 percent of their body weight before the rains return. Milk yields and reproductive performance fall and mortality rises.

Supplementary feedstuffs are scarce and expensive, but home-grown legume forages are likely to offer a solution. However, livestock owners have little access to land, few implements for cultivation and little money to spare for fertilizer.

ILCA's Subhumid Zone Programme has addressed these problems by introducing "fodder banks" of forage legumes which are cultivated and partially fertilized by the animals themselves. Large numbers of animals are crowded onto the 2- to 4-ha fodder bank areas at the start of the rains. They graze the remaining vegetation, their hooves break up the soil surface and their dung and urine provide fertilizer to help in the establishment of the forage legumes. The fodder bank is then sown with successfully tested varieties of *Stylosanthes* (e.g., lucerne and stylo) and 150 kg/ha of phosphate fertilizer. By the end of the rainy season such fodder banks yield 4 to 6 tons of dry matter per hectare, with a crude protein content of at least 13 percent.

The fodder banks are made available to animals periodically during the dry season, giving high-quality feed and boosting production at a time of the year when the animals are accustomed to only a small amount of low-quality grazing.

The ILCA package has been enthusiastically received by local herders and by Nigeria's Federal Livestock Department. Now 23 fodder banks exist in ILCA's case study areas, some of which have been started by the pastoralists themselves after seeing the success of banks grown by ILCA's team.

SOURCE: International Livestock Center for Africa (ILCA), *ILCA Annual Report 1983: Improving Livestock and Crop-Livestock Systems in Africa*, Addis Ababa, Ethiopia, 1983.

land is particularly scarce, or where the numbers of landless Africans are increasing.

In a similar vein, research begun in 1979 on dual-purpose (milk and meat) goat production systems in Kenya show promising results in developing low-cost, low-risk technologies able to accommodate the land, labor, and capital constraints faced by resource-poor farmers (48). In this work, the major factor limiting improved production was found to be the poor quality and scarcity of feed, especially during the dry season. To compensate, the researchers introduced an indigenous legume, *Sesbania sesban*, which provided supplemental protein for goat diets, improved soil fertility and provided fuelwood and a living fence. Introducing sweet potatoes into the system and using its vines as supplementary feed was also found to be effective.

Despite these promising results, a number of problems need to be addressed. Paramount is the need to incorporate veterinary care into such programs (ch. 11). Peste de Petit Ruminant (PPR), a respiratory disease, poses a particularly severe threat because it is widespread in Africa and can wipe out an entire flock or herd quickly. Preliminary results show that innoculating small ruminants each year with tissue cultured rinderpest inoculation can control PPR under village conditions (36), but the problem remains whether resource-poor farmers are willing to invest in vaccination. Unpublished cost-benefit data suggest attractive returns (36), but other social, technical, and institutional factors must also be considered, not the least of which is the effectiveness of extension services in reaching low-resource farmers.

Animal Traction

Animal traction refers to the use of animals, primarily cattle, for farming activities like land preparation; sowing, weeding, and harvesting crops; and transportation. Substituting animal for human power can reduce human labor while increasing the farmer's ability to cultivate more land per day, and with less drudgery. Savings in labor, however, are offset to varying degrees by the work needed to maintain the animals.

Some 10 to 20 percent of Africa's farmers use animals for traction, but the practice is steadily spreading. The area cultivated by animal traction is estimated at about 15 million ha, or 15 percent of total cultivated land. This average figure masks major variations at a regional level; the proportion cultivated by animal traction varies from no more than 2 percent in central and West Africa to 42 percent in eastern Africa. It reaches a high of 90 to 100 percent in Ethiopia and Botswana (41).

Even on farms where animals are used for plowing, manual labor is often relied on for other farming activities. For example, only 5 percent of farmers who plow with animals use them to pull mechanical weeders (41). Overall, animal traction makes only a small contribution to the overall power requirements of African agriculture, which is still about 90 percent dependent on human labor. Several West and Central African countries are nearly 100 percent dependent on human labor.

Although animal traction can be used for deep plowing, which sometimes can lead to increases in crop yields, few farmers use the technology to improve tillage. Rather, animals are mainly used to expand the area cultivated and improve labor efficiency, and these factors lead to increases in overall production rather than yield increases per hectare (38).

It has been argued convincingly that the acceptance and viability of animal traction, as well as use of tractors, is a function of the type of fallow practiced by farmers (38). The ability to benefit from animal traction is hampered by the presence of tree roots and stumps in regions where tree fallow prevails. This suggests that animal traction or tractors become more viable under progressively more intensive bush-fallow and grass-fallow systems (38). Studies of the relationship between fallow type and shifts from hand cultivation to animal traction provide the following general observations (38):

- The transition to the plow would not be cost effective in forest and bush fallow systems due to the high overhead costs required for removing stumps and for animal maintenance.
- A distinct point exists in the evolution of agricultural systems where plow use becomes economically feasible.
- This point is conditional on soil types and soil fertility: the transition would occur sooner for hard-to-work soils (clays) and for soils which require high labor inputs for maintaining soil fertility.

The high costs involved in buying animals and equipment can deter resource-poor farmers from adopting animal traction. Oxen and equipment may cost one to three times a farmer's annual income, depending on the amount of equipment included (20,38).

Although animal traction can be used to double or triple rates of return by using mechanization to free up labor, it can be as long as 5 years before these rates are reached (21). Also, the economic return from animal traction seems to decrease if too much equipment is introduced at once or if it is too complex (20). For example, in some cases earnings per worker and even per hectare on the highly mechanized enterprises (ones using a seed drill, hoe lifter, and cart) can be lower than on farms using only a seed drill).

Where draft animals are already in use, inadequate or untimely access to draft animals can result in a failure to plant at the optimal time and, thus, significantly reduce yield (37). Making more efficient use of draft animals can make important contributions to improving yields. Improving animal health offers one important avenue to increased efficiency (ch. 11). Improvements in, and diversification of, animal traction equipment offer others.

ILCA has modified the traditional Ethiopian maresha plow so that it can be pulled by one ox instead of two in one attempt to address the problem of insufficient draft power. This simple change could have significant impact in a country where only one-third of the farmers own two oxen. Using the new plow, a single well-nourished ox can plow 60 to 70 percent of the area normally covered by two oxen, and the farmers can make the inexpensive plow modifications themselves (19). Initially enthusiasm was high based on result from tests at the research headquarters. However, subsequent on-farm studies identified a number of problems that have dampened expectations and reinforced awareness of the need to promote increased farmer participation in technology development (29).

Increased attention is now being directed to other modifications of the maresha that, based on on-farm trials, offer great promise (23). One modification is the development of a terracing plow that could make important contributions to efforts to reduce soil loss, increase water conservation, and provide stable crop yields.

Another modification is the development of a broadbed and furrow maker that could promote better use of the nearly 100 million hectares of Sub-Saharan Africa's vertisols. Vertisols are clay-rich soils that have a very high water-holding capacity and thus, when wet, tend to get waterlogged and sticky. When dry, they become hard and cracked. To grow anything besides a few waterlog-tolerant crops, elevated beds need to be built to increase water drainage and evaporation. Making such broadbeds in these difficult to work soils is traditionally done by hand, and requires labor inputs of about 60 hours/ha. The maresha broadbed maker, costing about $25 for modification, can cover the same area in about 16 hours using a pair of oxen. Although power requirements are about 50 percent higher than for the traditional maresha, power needs are considered well within that which can be provided by a pair of local zebu oxen (23). Improvements in total labor productivity are estimated to be at least 40 percent, while measured yield gains of bread wheat and teff were found to be about 80 percent and 25 percent higher, respectively.

Increased use and modification of animal traction technology in crop production, including plowing, planting, and weeding, show significant promise for increasing labor productivity. Weeding—the second most important labor bottleneck after plowing—can be done six to seven times faster using animal traction compared to hand weeding (22). Increased attention could also be directed to other underdeveloped uses of animal traction. ILCA for example has developed an ox-drawn scoop that can be used to dig and remove silt from ponds to store water for the dry season, or to develop aquaculture (19). Animal traction as a pumping technique in small-scale irrigation schemes may also deserve greater attention as does animal-driven transport.

Expansion and diversification of animal traction technology in promising regions will require access to equipment and will increase demand for repair services and spare parts (38). Large factories in several countries, for example, Senegal, Mali, and Ivory Coast, have been set up to manufacture animal traction and transport equipment. These tend to be parastatal operations and their production capacity is generally much higher than existing demand. As such, these operations tend to be subsidized and are given access to preferential credit terms (44). Increased use of animal traction may make such operations cost-effective in the future. However, increased attention should be directed toward supporting small private, locally based, enterprises. Significant benefits exist in supporting the training of blacksmiths in equipment production, maintenance, and repair where these artisans are widely dispersed and integrated into villages, and where they provide services directly to local farmers (10,38).

Photo credit: U.S. Agency for International Development

Mastering the use of animal traction can take as long as 5 years for farmers unfamiliar with it. Here a Senagalese farmer practices plowing during the dry season.

Aquaculture[1]

Aquaculture refers to practices by which fish and other aquatic organisms are cultivated, much like any other agricultural product, rather than caught from rivers, lakes, or oceans. Land, water, and climate combinations in many places in Africa have potential for supporting aquaculture. Appropriate technologies have been demonstrated that are profitable and within the management capability of low-resource farmers (15). By regulating stocking and improving pond design, small pond systems can be the basis of modest managed fisheries.

Ponds built for aquaculture can be designed to play a role in a larger soil and water conservation program. Ponds help slow the erosional force of runoff water and can reduce downstream flooding. The water stored in ponds can be used during the dry season for watering stock, irrigation, drinking, washing, recreation, and to support wildlife. Therefore, fish production facilities can be combined with many other uses.

The management used in aquaculture can be extensive—using random stocking of available fish species into existing ponds—or intensive—using exotic species raised on processed feed in ponds built with mechanization. Extensive and semi-intensive approaches currently hold the most promise for resource-poor farmers (6, 14,15). Many unsuccessful efforts to establish aquaculture in Africa bypassed extensive management and attempted to introduce intensive systems (15). Extensive systems, however, are better suited to and more likely to be adopted by low-resource farmers becomes of their lower capital input and lower financial risk (34).

Farm systems could be studied to design aquaculture systems that are compatible with farmer labor and financial constraints. As farmer familiarity and competence in managing aquaculture increases, efforts can be directed to emulate the more productive but more complex "polycultures" such as those of China. As with intercropping or mixed-species herding, polyculture ponds increase yields because the mix of species more efficiently uses available resources than can any one species (14).

One of the simplest ways to enhance fish production in ponds is by the use of fertilizers. Chemical fertilizers or organic material can be used to stimulate natural fish food production. Fish may also be fed directly, but products that provide a nutritionally complete diet are usually expensive and in short supply in less developed countries. The same is often true of chemical fertilizers. Nevertheless, some locally available farm byproducts such as animal manure, cereal brans, and crop residues sometimes can be used to supplement natural foods in ponds to enhance fish production. Efforts to increase aquaculture production should include identification of these local feed/fertilizer resources and the design of production systems that take advantage of this local availability.

Integrating fish, livestock, and garden production into a single system—a practice common in the Orient—may be applicable in select cases in Africa. Local application may take various forms. A typical situation might be for a farmer to have a few small fishponds, with water enriched with runoff from a small poultry or stock pen. The enriched water from the pond, besides producing fish, would also be used to irrigate and fertilize a vegetable garden. Garden wastes would then be fed back to the stock or be put into the ponds. The diversity of such an integrated system reduces the risks associated with any single part of the system and also provides a variety of products for household use or local markets. Small operation can usually be built and maintained with family labor and can be programmed to keep within existing demands for time and food, or cash crop production. Such systems require relatively little capital and remain in the control of the producing family.

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[1] The material on fisheries is based primarily on John Grover and Stephen Malvestuto's contractor report (app. A) and an unpublished description of the U.S. Peace Corps' fisheries work by Harry Rea and John Zarafonetis, June 29, 1987, Washington, DC.

Planners, however, must also evaluate and mitigate any potential adverse health impacts that may arise from aquaculture operations—both on the stock produced and on people. Disease or parasite outbreaks are commonly the most severe constraints to aquaculture development in a region (1). For example, greater attention could be directed to evaluating the threats of increased influenza pandemics that may arise from the spread of aquaculture operations, particularly systems that closely integrate fish, waterfowl, and swine production (39). Threats of introducing or exacerbating schistosomiasis is another important concern. Agrochemical use in farming operation should also be evaluated to avoid problems of introducing toxins (e.g., pesticides) that commonly accumulate in aquatic food organisms. Aquaculture operations can also generate their own pollution problems, such as nutrient build-up, for which mitigation plans may be needed (1).

Experience with promoting integrated aquaculture systems in Africa is small, although initial results of the Peace Corps' work in a few areas, such as Tanzania, for example, seem promising (14). Reviews of aquaculture development elsewhere suggest that it is best approached in stages. Integration of fish production with other forms of animal husbandry may follow but may be too complicated during start-up (14).

The Peace Corps, initially with support from Oxfam and later from AID and the Zaire government, have been involved in aquaculture in Zaire since 1973. OTA asked the Peace Corps to outline briefly what factors are most important for successful aquaculture development, based on their experience (box 10-5). These lessons seem to provide useful guidelines for supporting aquaculture development in other parts of Africa as well.

Box 10-5.—Elements of Successful Aquaculture Development in Zaire

The Peace Corp's Fish Culture Expansion Project in Zaire began in 1978, building off earlier work and feasibility studies dating to 1973. The earlier experience demonstrated the technical and economic feasibility of small-scale *Tilapia* culture in family-operated fishponds. This work provided an understanding of local conditions, including the biology of fish production in the area and the culture and institutional framework around which the project was to be oriented. The following points have been identified as the most important elements of successful aquaculture development based on at least 10 years of experience with the project.

- *Farmer interest in and familiarity with fish culture.* In the project area, people have harvested river fish for centuries. They liked *Tilapia* and were interested in the project. Although colonial introduction of aquaculture was unsuccessful, many people were familiar at least with what fishponds were. Therefore, Peace Corps Volunteers (PCVs) did not have to introduce a completely foreign technique.
- *Tilapia culture is ideal as a first form of intensive animal husbandry. Tilapia* are extremely hardy fish, they rarely die from disease or mismanagement, and they reproduce in a wide range of conditions. Farmers left their village for weeks at a time, in certain cases, and returned to find not only that their fish had survived, but also had spawned. Little capital investment is necessary. Fingerlings are inexpensive, ponds can be dug by hand when labor is not needed for tending other crops, and inputs are available locally (feed, organic fertilizer, and fingerlings for restocking).
- *Excellent technical and logistical support.* A technically qualified Associate Peace Corps Director has been responsible for the project nearly continuously since 1974. Most PCVs have participated in pre-service technical training and are involved in all planning processes. This technical training not only has provided PCVs with the needed technical and extension skills but also instilled in the locals high levels of confidence, enthusiasm, motivation, and, perhaps most importantly, a sense of direction.
- *PCVs set high standards for project ponds.* High work quality standards are expected from participants in the demonstration ponds. This often means withdrawing support from those farmers who are unwilling or unable to meet adequate standards and commitments. The re-

maining farmers each build several high-quality ponds that serve as models for other interested farmers. Failure to set standards for pond operations has been a major shortcoming of several other technical support programs.

- *Focus on management.* Even though the mechanics of fish culture are simple and the risks considerably lower than with other forms of animal husbandry, the concepts can be difficult to understand. Concepts such as stocking, feeding, growth, and production rates—let alone pH and oxygen cycling—are unfamiliar to farmers that have never raised animals. Proper management is the reason that some farmers produce two to three times more fish than their neighbors.
- *Development of local infrastructure.* The Zaire fish culture project demonstrates that this type of agricultural development is possible even with minimal national government support. The program's focus has always been on the individual farmer. Fingerlings are produced and distributed locally, experienced farmers advise new farmers on site selection, pond construction and management, and farmers meet regularly to discuss problems. Numerous seminars, meetings, and field trips are held before there is ever talk of forming a group. Farmers get to know each other and come to rely on each other for advice and assistance. The result is the development of a local private infrastructure capable of taking over PCV responsibilities.
- *Long-term commitment.* A 10- to 20-year commitment may be necessary for introducing aquaculture into a region, although shorter support periods may be possible for particular sites. The Peace Corps recognized the need for a long-term view when introducing the technology into a village, and plans to be actively involved from 4 to 8 years depending on the village. PCV input is designed to last long enough for farmers to see positive results, but then it is phased out as local management skills are developed.

SOURCE: Harry Rea and John Zaraphonetis, unpublished cast study, U.S. Peace Corps, Washington, DC, June 19, 1987.

POTENTIAL

Improvements in existing low-resource farming systems for much of Africa will be predicated on access to increased income so there is cash available to invest in inputs to enhance productivity, such as improved seeds, fertilizer, and labor. Livestock, particularly small ruminants and poultry, provide the most important source of income for subsistence farmers. The improved diets that result from introducing animals into farming systems further enhances the production potential. So, too, do livestock systems that help modulate labor demand—i.e., those that can employ labor during periods of underemployment but do not place heavy demands on labor during seasonal labor bottlenecks.

Promoting improved integration of crop and livestock production holds strong promise for Africa. For the region as a whole, an extra animal in the cattle population on a mixed farm correlates with an additional one-quarter hectare of crop land, a 200 kg incremental grain output per year, as well as an additional 30 kg of meat and 38 kg of milk (3,4). Research also shows that integrating animals into a small farm increases returns over cropping alone. For example, maize grown solely for human consumption recovers 39 percent of the crop's energy and 20 percent of the protein. When the materials left from food preparation are fed to an animal, nearly 50 percent of the crop's energy and 30 percent of the protein is used. Small ruminants offer particular advantages and opportunities within low-resource agricultural systems and deserve increased attention (49).

Research on improved integrated crop/livestock management systems is new but shows great promise and seems well adapted to meeting the particular needs and constraints of resource-poor farmers. Development of other technologies, such as new or adapted implements to make more effective use of animals, promises to provide improvements in production efficiency. Animal traction enables farmers to cultivate more land and reduce drudgery, and helps improve nutrition for the farm family. Animal disease, particularly trypanosomiasis, severely limits animal use in much of Africa. Disease control, particularly through expanded use of trypanotolerant breeds and improved management systems (ch. 11), offer hope for future wider application of mixed crop/livestock technologies.

Also important for the resource-poor farmer is the increased food security that can be achieved through diversification of food and income sources made possible by mixed crop/livestock production. Aquaculture, for example, potentially could be a part of farming systems throughout the humid lowlands, tropical highlands, and wherever else water is available to supply small, year-round ponds.

PROBLEMS AND APPROACHES

Currently, about 75 percent of African livestock are raised on small, primarily subsistence, farms where animal nutrition is the most limiting factor in increasing animal productivity. It is likely that this will remain the norm for some time to come (31). Improving efficiencies by better integrating crops and livestock to facilitate small-scale mixed production is thus a logical focus for the immediate future.

Despite the predominant importance of livestock in arid and semi-arid regions, efforts to develop technology for pastoralist systems largely have been unsuccessful, with the possible exception of veterinary interventions. A reassessment of goals and strategies is needed so lessons learned from mistakes are better used in planning future activities. Further, soliciting knowledge and participation of herders themselves is now seen as an essential component of successful interventions (13,45,49). AID and others have expressed an emerging agreement that the prime emphasis in the livestock sector at this time should be to support the subsistence base of pastoral herding rather than to stress commercial meat production (45). Increased attention needs to be directed toward resolving the resource conflicts between pastoralists and sedentary agriculturalists. The problems that emerge where farmers move into grazing areas that pastoralists require for dry season browse are particularly acute.

The potential of livestock development in wetter regions is more promising. Livestock remain underexploited in subhumid regions, particularly for animal traction and integrated crop/livestock systems. Cattle production in the humid zone will continue to be restricted by trypanosomiasis, but small ruminant production using leguminous trees to complement other feed sources seem promising although, here too, there are disease problems to combat.

More broadly speaking, the need exists to better account for the interaction between crops, trees, livestock, and wildlife—as well as the social and cultural values that emerge at the interface of human and natural systems. Perhaps the single most important objective should be to recognize and take advantage of complementary areas and mitigate against areas of conflict. One example is the potential links leguminous trees and shrubs can play in simultaneously providing access to high protein forage for livestock, improving soil fertility for crops, and reducing pressures on the surrounding environment by providing fuelwood, stabilizing soils, and enabling more intensive production.

Conversely, an accounting is also needed of possible deleterious interactions. For example, plants that may be best for nitrogen fixation may produce forage that is toxic for animals (33). Plant breeders' efforts to increase grain yield may affect the needs of African farmers who use crop residues as a source of livestock feed. Farmers in Mali, for instance, rejected an improved variety of cowpea because the improved crop yield also significantly reduced the amount of residue for fodder (49). In a similar case, new bird-resistant varieties of sorghum contained increased tannin, which reduced the utility of plant protein. Plant breeders must consider these potential trade-offs and look at "whole plant" uses in order to respond to the needs of low-resource farmers (31).

Animal traction, although not prevalent in Africa compared to other developing regions, is steadily increasing in importance. Fostering increased use of animal traction has a significant role to play in the future of African agriculture. It is necessary, however, to consider environmental and sociological factors before promoting animal traction in an area. Structure of the soil, relative content of clay to sand, and erodibility are obvious considerations. Sociological factors more difficult to measure are also important, however. For instance, consider the analysis below of the problems encountered trying to promote animal traction in the Dukolomba region of Mali (25):

> When elders of Dukolomba, upon being confronted with the ox-drawn plow by the French, told the laboring youth of the village that the "cow hoe," as it is called, would wear out their soil too quickly, they are, as we have seen, not lying. But it wasn't the soil that they were trying to economize on. As the decision makers, but not the laborers, in the family firm, these elders felt that with the labor-saving device of the plow they would lose control over the youths, who feeling less needed by the family, would drift away, either to the Ivory Coast or into their own separate firm. Thus in purchasing a plow, the elder would lose not only its price but also control over labor which he could use to advantage throughout the year. The youths were to be shamed into staying at home by the spectre of famine which would result from their being absent during the moundmaking and the weeding season. Both elders and youths concur on this explanation of Dukolomba's early avoidance of the plow.

Although research and technology development in support of integrated crop/livestock systems is scant, that which does occur is more common in the international research centers than in African national research centers (31). This is a serious omission from national research programs given the prevalence of mixed farming systems in Africa and the potential gains from improved crop/livestock integration.

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Chapter 11

Improved Systems to Reduce Losses

CONTENTS

Page
Integrated Pest Management 257
  Summary 257
  Options for Managing Pests 258
  Potential 261
  Problems and Approaches 263
Improving Animal Health 264
  Summary 264
  Veterinary Support 265
  Animal Nutrition 266
  Potential Gains From Improved Animal Health 269
  Problems and Approaches 270
Post-Harvest Technologies 273
  Summary 273
  Opportunities for Improvement 274
  Potential 279
  Problems and Approaches 279
Chapter 11 References 281

Boxes

Box *Page*
11-1. State of the Art: Control of Major Livestock Diseases in Sub-Saharan Africa 267
11-2. Women Invent New Technology for Smoking Fish 280
11-3. Improved Charcoal Stoves 281

Figure

Figure *Page*
11-1. The Resurgence of Rinderpest in Africa and the Near East 271

Table

Table *Page*
11-1. Effectiveness of Plant Protection in 15 West and Central African Countries 262

Chapter 11

Improved Systems To Reduce Losses

This chapter examines various technologies available to reduce pre- and post-harvest losses in African farming systems. The first section deals with the various elements of integrated pest management—a strategy that aims at integrating the best mix of available methods to control losses of crops due to pests. The second section examines technologies to improve animal health in low-resource agriculture, both grazing and mixed crop/livestock systems. Improved animal health has the potential to reduce direct losses due to mortality, as well as improve productivity of livestock. Veterinary support and improved animal nutrition are the major areas examined. The final section looks at a host of technologies that fall under the general category of post-harvest technologies. Although many technologies specifically address themselves to reducing post-harvest losses, such as improved preservation and processing, others are more important for their ability to reduce drudgery and increase efficiency of post-harvest activities.

INTEGRATED PEST MANAGEMENT[1]

Summary

A wide range of insects, mites, fungi, bacteria, viruses, weeds, vertebrates, and other pests plague Africa's resource-poor farmers and herders. In fact, an estimated 30 percent of the production from some crops is lost in the field or in storage (1,13,56). Although only certain crops suffer such severe pest damage and some experts find that typical losses are lower, the problem is still one with significant implications for food security. The vulnerability of farmers to pest-induced crop loss is likely to increase as more land is planted with genetically uniform monocultures and as the genetic base of crops narrows.

Pests also present problems for public health and livestock. Malaria persists as the most important infectious disease in Sub-Saharan Africa despite attempts to control the vector mosquitoes with insecticides and massive programs to distribute antimalarial drugs (51). The two major arthropod-born diseases of livestock, trypanosomiasis (transmitted by tsetse flies) and East Coast fever (transmitted by ticks), prevent livestock production in large areas of Africa (25,64).

Pest control methods include: quarantines to prevent entry of new pests into new areas; pest-resistant varieties of crops and livestock; cultural controls, such as crop rotations and intercropping; biological controls; and a variety of biological and chemical pesticides.[2] Integrated Pest Management (IPM) is a pest control system that draws on these various pest control methods to provide the most effective mix of available techniques (68). Criteria for determining the optimal methods for resource-poor farmers and herders include (3,39,43,71):

- **Technical-effectiveness:** pest damage is kept to an acceptable level.
- **Cost-effectiveness:** methods are affordable and economically advantageous.

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[1] This material is based primarily on the OTA contractor report prepared by Dale Bottrell, University of Maryland, (app. A).

[2] "Biological" pesticides refer to those derived from plants, bacteria and viruses, and fungi. "Chemical" pesticides refer to all other pesticides (i.e., the synthetics).

- **Sustainability:** system is designed for long-term effectiveness, and required inputs are accessible and reliable.
- **Safety:** human and environmental health are ensured.

Developing IPM packages is expensive because they are information-intensive and require trained scientists to research the basic biology of the pests, their natural enemies, and how both interact with the host. Using the packages does not have to be expensive, however. Resource-poor farmers and herders already practice pest control methods that can be improved by scientific knowledge, and the tasks of maintaining the systems—timing of planting, cultivation practices, scouting the field for pests, and so forth—are well within the reach of most African farmers, if they are given training and support (23). IPM may also help reduce problems associated with uncontrolled chemical pesticide use in developing countries. These include human and environmental contamination arising from misapplication of pesticides and the high cost of imports when foreign exchange is scarce.

Development assistance to Africa's resource-poor farmers and herders could benefit from a longer term, sustainable approach that calls for increased emphasis on IPM. Using chemical pesticides alone is a common short-term approach, but a more diversified approach that draws on various pest control methods will be more effective over the long term. Chemical pesticides can be expensive and access to them is unreliable for many resource-poor Africans. Subsidies shift the economic burden to governments, but still drain national economies. Furthermore, free pesticides discourage farmers and herders from exploring sustainable alternatives (58).

IPM is a concept of pest control that combines different aspects of available pest control methods. Central to IPM are efforts to maintain pest levels at non-injurious levels, rather than trying to eradicate all pests. It is an information-intensive technology that requires biological and ecological knowledge about the pest, its habitat, and the pest's natural enemies—e.g., their population dynamics, physiology—and constant monitoring of pest levels to keep them below predetermined economic thresholds, beyond which levels of damage are not affordable (50,72).

IPM usually contains a variety of components. Quarantines offer the first line of defense against the introduction of new pests to an area. Pest-resistant varieties of crops are used to minimize damage and increase crop survival. Cultural controls include agricultural practices that deter build up of pest populations and/or encourage predators, and parasites and pathogens that act as biological controls on pests. Biological pesticides, which tend to be more target-specific and less damaging to the environment, are generally preferred to chemical pesticides. Chemical pesticides, especially insecticides that kill pests and beneficial insects alike, are used conservatively; this better enables natural enemies to "track" changes in the population size of the pests—increasing or decreasing in number in response to the status of the pests.

Options for Managing Pests

Quarantines

Quarantines are regulatory techniques to prevent the entry and establishment of new plant and animal pests in a country or area. For example, the cassava mealybug (*Phenacoccus manihoti*) and the cassava green mite (*Mononychellus tanajoa* complex) were accidentally introduced into Africa from South America in the 1970s. These exotic pests now infest at least 60 percent of the cassava-growing area of Africa and cause annual losses estimated at nearly $2 billion (22). The possibilities for introduction of exotic pests into new areas of Africa can be expected to increase as the frequency of contact among nations increases.

Quarantines require a high degree of coordination at a national or regional level. A dilemma common to almost all Sub-Saharan countries is the inability to enforce quarantine regulations at ports of entry. While most countries have some form of quarantine regulations, few are effective (3). A study by the Food and Agriculture Organization (FAO) of quarantine programs in West and Central Africa showed that the quarantine personnel were not technically qualified because of inadequate training (60). Further, regional mechanisms for cooperation, so important in regulating the spread of pests, are not fully used because of political tensions and poor communications. Their cost-effectiveness in Africa cannot be addressed because data—e.g., on the origin, volume, and economic worth of the produce—are lacking (3). Quarantine experts concur, however, that although quarantine programs do not guarantee complete protection, if properly implemented they greatly reduce the risk of costly accidental introductions.

Pest Resistance

Pest resistance refers to the use of varieties of plants and animals which are resistant, tolerant, or unattractive to the pest. In recent years, plant breeders have bred resistance into, or identified resistance sources for, a range of basic African food crops, including sweet potato, yam, cocoyam, cowpea, sorghum, maize, rice, millet, and cassava. Recent significant accomplishments in pest resistance include the development of cassava varieties that are genetically resistant to mealybug and green spider mite (21). Resistant cassava clones are being distributed to Nigerian farmers, and seeds are being dispatched to national programs throughout Africa. Improved lines of cassava with resistance to the African cassava bacterial blight (caused by *Xanthomonas campestris pv. manihotis*) also have been developed. Several improved lines give yields up to 30 tons per hectare (40) and have out-yielded local standard varieties by 2 to 18 fold primarily due to their disease resistance (32,33).

Cultural Controls

Cultural controls involve manipulating farming practices to alter the environment so it is less favorable for the pest or more favorable for the pest's natural enemies. Virtually all resource-poor farmers use cultural controls. Intercropping, for example, is a widespread practice which helps reduce pest problems. Different crop species can also be grown on a rotation basis, thereby disrupting the lifecycle of many pests. For example, groundnuts or other nematode-resistant crops are used to disrupt the populations of this pest, which, if left untreated, can devastate cassava yields (22). Other traditional African cultural practices known to reduce pest populations include burning undesirable vegetation, planting crops during pest-free times of year, and cultivating to control weeds (43). For example, Kenyan farmers, recognizing the link between low soil fertility and *Striga* weed, use crop rotations and fertili-

Photo credit: Donald Plucknett/Consultative Group on International Agricultural Research

Pest resistance has been identified for a number of important African crops including sweet potatoes like those being planted by this Rwandan woman.

zation with manure to control this parasitic plant which, if untreated, can virtually eliminate yields of cereal grains (11). These techniques are often the least expensive and most effective methods for suppressing insects, disease agents, and weeds (3,17).

Biological Control

Biological control involves either the propagation and release of new natural enemies—predators, pathogens, and parasites—against target pests or the encouragement of practices that preserve and increase the effectiveness of existing natural enemies. It is a process of reinforcing nature's own system of checks and balances that can be used by the individual farmer. Traditional agricultural practices, especially intercropping, encourage natural biological control of pests, and unless disrupted by pesticides or other means, natural predators and parasites keep many potential native insect and mite pests in check. No one must purchase this form of crop protection and it continues to benefit farmers as it has for as long as traditional agriculture has existed.

Classical biological control, which involves propagation and release of new natural enemies, has been applied in Africa to a relatively small number of foreign insect, mite, and weed species. Whereas naturally occurring biological control involves no cost and requires no institutional support to maintain, classical biological control involves costs to find, import, rear, and distribute the new natural enemies and requires institutional support to maintain the program.

The Africa-wide Biological Control Project of Cassava Pests, set up by the International Institute of Tropical Agriculture (IITA) in 1980, is the largest organized effort in biological control in the region. This project is responsible for successfully introducing a parasite for control of cassava mealybug (*Phenacoccus manihoti*). Since 1982, a parasitic wasp *Epidinocarsis lopezi*, imported from South America, has been released at 54 different sites. The parasite has successfully established itself at most of the release sites, covering roughly 9 percent of the total land planted with cassava in Africa, and is spreading to other areas. In Nigeria, where it has been studied most intensively, mealybug populations have been reduced to non-injurious levels wherever the parasite has become established. The parasite will now be released in other mealybug areas as part of a $20 million biological control program (9,15, 26,33). Worldwide, economic returns from classical biological control programs are estimated at $30 for every $1 invested (49).

Pesticides

Pesticides include a variety of chemical substances that can be divided into biological (plant, bacterial and viral, and fungal-derived) and chemical (synthetic)[3] pesticides. Pyrethrin, derived from chrysanthemum plants, is a biological pesticide that was used in traditional agricultural systems in Africa, and is now produced commercially in Kenya (74). In general, biological pesticides are a fairly recent area of research, and although they are currently a minor component of pesticide use, their importance is expected to increase. Some new pesticides will blur the area further between biological and chemical forms. Future pesticides are likely to be based on insect pheromones, microbial products, naturally occurring insect growth regulators, etc. (74).

The primary benefit of pesticides is they can be marshalled quickly to give rapid control of a threatening pest. For example, minimal applications of the insecticide permethrin to cowpea in Nigeria reduced the major insect pest populations 50 to 85 percent and increased yield sevenfold (42). The dramatic impact that pesticides can have was also illustrated by their role in controlling the 1986 locust and grasshopper outbreaks. As late as August, these insects were expected to destroy the crops of tens of millions of Africans. Reuter News Agency warned of an invasion of "biblical proportions." However, by the end of October, 1986, cooperation and technology had been generally successful in protecting crops in the affected region (3). In Senegal, for example, crop losses were kept to about 5 percent (73). Pesticides provide short-term control, however, and grasshoppers and locusts are recurrent African pests. For instance, desert locust outbreaks are occurring in 1988 and control is likely to be more difficult than in 1986.

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[3] Biological pesticides can be modified and, then, also considered "synthetics" but the term refers more often to pesticides without biological bases.

Chemical pesticide use in Africa varies considerably among crops, pests to be controlled, and geographical region. Large areas of cash crops (cotton, coffee, banana, cocoa, etc.), usually planted as monocultures, generally receive the greatest quantities of pesticides, but the chemicals are also used on some food crops, especially the high-yielding varieties of cereal grains and vegetables.

Concerns exist that use of chemical pesticides has been promoted more quickly in Africa than has the capability to ensure their effective and safe use (3). In particular, critics point to the export by industrialized countries of pesticides that are restricted or banned for sale in their domestic markets. For example, about 25 percent of U.S. pesticide exports were chemicals that have been heavily restricted, suspended, or prohibited in domestic markets (6,67). Many Sub-Saharan countries lack the infrastructure to govern the importation, domestic use, and disposal of pesticides. Of 15 West and Central African countries included in a 1985 survey, 5 had no laws to govern the importation or use of the materials. Even with pesticide laws, most governments lack the infrastructure required to enforce them. Farmers are seldom prepared to handle pesticides. Often they cannot read or understand pesticide labels, or they use pesticides from unlabeled containers. They rarely possess (or wear) protective clothing or safety devices, and may carelessly dispose of the leftover materials. African countries seldom have medical personnel and facilities trained to diagnose and treat cases of pesticide poisoning, and extension efforts to train farmers on correct use of pesticides are often minimal (6,44). Consequently, developing countries account for up to 50 percent of pesticide applicators' acute poisoning and 73 to 90 percent of fatalities, even though they use only 10 to 25 percent of the world's pesticides (2,6,12,19,37).

Apart from the concern over health and environmental impacts in Africa, increased pesticide use is being challenged by growing genetic resistance in pest organisms. In 1984, 638 pest species worldwide (428 arthropods, 50 weeds, 150 plant pathogens, and 10 small mammal pests and plant-attacking nematodes) were known to possess strains resistant to one or more previously effective pesticides (54). Resistance has appeared in many serious pests affecting agriculture, livestock, and public health in Africa (3).

Potential

IPM is a strategy designed to provide the best mix of available pest control methods and thus it is a responsible approach to pest management. In a sense, virtually all resource-poor farmers and herders in Africa practice a form of "integrated pest management." They depend on a combination of traditional practices such as intercropping, using pest-resistant local varieties when possible, and enhancing naturally occurring biological controls over certain pests. However, IPM programs are just beginning to benefit from scientific advances in understanding of the ecology of pests and are beginning to be implemented in a way consistent with local agricultural and socioeconomic conditions. Management information is the primary input required for IPM. The potential of the technology will depend, in large part, on how successfully traditional and modern knowledge on pest control can be merged. Farmers are an important source of information on local pest resistant varieties, many of which can be further improved by scientific research.

Implementing effective IPM programs throughout Africa will take many years, but because IPM represents an effective approach to pest management, benefits will accrue as countries move in the direction of using this method. Some countries (e.g., Central African Republic, Somalia, or Guinea) have little government infrastructure and few pesticide laws, delivery systems, personnel, facilities, or cooperative links with neighboring countries and international centers (table 11-1). In these countries, a minimum of 10 years would probably be required just to create an organizational structure necessary to develop and sustain an effective long-term effort in pest and pesticide management (3).

Quicker results could be expected in countries (e.g., Nigeria, Kenya, Cameroon, Ivory Coast) with more developed pest management infrastructure, assuming pest management is given a higher priority and increased attention is given to an integrated approach rather than simply relying on pesticides alone. Greater attention should also be directed to assessing what influence pesticide subsidies may have on adopting the best mix of pest management technologies. Nigeria, for example, has substantial government and scientific resources. Pesticide enforcement procedures and improved quarantine programs could be in place in a few years. Work toward developing IPM programs for selected crops could begin immediately, drawing from existing scientific knowledge and farmers' experience and practices. Within 5 years, 10 to 20 percent of farmers of specific crops such as rice (where a rich knowledge base already exists) could be using partial IPM packages. Within 10 years, an estimated 50 percent of the farmers could be using IPM technology (3).

As biological pesticides become better researched, they are likely to become a more important tool in the IPM arsenal. For example, Neem trees (*Azadirachta indica*) produce repellents and feeding deterrents for a broad spectrum of economic agricultural and household pests. Neem is being grown commercially in several African countries (69). Endod (*Phytolacca dodecandra*) is a plant that has proven effective as a molluscicide. This plant, which can be grown in much of Africa, holds promise as a control agent for schistosomiasis, a snail-transmitted disease (69). Several viral-based pesticides are important in IPM systems, for example, in soybean production in Brazil

Table 11-1.—Effectiveness of Plant Protection in 15 West and Central African Countries[1]

	Percent of countries in category			
Area of plant protection	Good	Moderate	Poor	No information
Plant protection personnel	7	40	46	7
Pest control equipment	0	47	47	6
Support facilities	0	13	80	7
Plant protection laboratories	0	47	47	6
Pest diagnostic laboratories	0	47	47	6
Plant quarantine buildings, equipment	7	40	40	13
Pesticides available locally	0	43	20	27
Plant protection service	7	20	40	33
Agricultural schools, training facility	7	66	20	7
Specialized plant protection curriculum	7	33	53	7
Institutionalized research	7	53	20	20
On-farm, applied research	0	13	74	13
Pest lists	13	47	33	7
Pest distribution knowledge	0	47	40	13
Pest biology knowledge	7	7	13	73
Economic loss knowledge	0	27	40	33
Pest control knowledge	0	20	80	0
Overall strength				
Extension	7	40	40	13
Research	20	54	13	13
Training	7	46	40	7

[1] Countries in survey were Benin, Cameroon, Central African Republic, Congo, Gabon, The Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Nigeria, Sierra Leone, Togo, and Zaire.

SOURCE: P.S. Teng, "Plant Protection Systems in West and Central Africa: A Situation Analysis," unpublished report to the U.N. Food and Agriculture Organization Plant Protection Service, August 1985.

and coconut production in the South Pacific (23).

Problems and Approaches

Interdisciplinary Approach to Filling Information Gaps

The development and implementation of technically effective and socioeconomically and environmentally sound pest control policies and programs is a major challenge facing Africa. Meeting this challenge will require a new approach, where experts accustomed to working in isolation in their own disciplines learn to work with others in an interdisciplinary team. Teams composed of traditional pest management disciplines (e.g, entomologists, plant pathologists, weed scientists); basic biologists (e.g., ecologists, taxonomists, geneticists); economists; and other social scientists are required.

IPM requires much greater understanding of the ecology of the pest/natural enemies/host complex than does the use of chemical pesticides. Gathering this information can be a slow process, but it can be facilitated by taking advantage of farmer and herder knowledge. Studying local pest control practices and how these fit into other agricultural activities can allow research and extension personnel to improve their effectiveness. Tapping the knowledge base of African pastoralists, such as how the Fulanis keep trypanosomiasis, ticks, and tick-borne diseases to low levels, may also provide researchers with methods to reduce livestock losses (16). IPM research personnel could use farmers' fields for much of their experimentation; extension personnel could organize demonstrations of new practices in these same fields and extend the demonstrations to other areas where conditions are similar.

The International Agricultural Research Centers and a few national institutions possess the interdisciplinary expertise required to foster this approach. Their efforts in breeding crops with pest resistance and developing cultural controls have already had a favorable impact. Universities in the United States have experience in the development of IPM systems and could serve as an important technical resource.

Improved Infrastructure and Management

A number of countries are hindered in their attempts to control pests by their lack of basic infrastructure, resources, and personnel (44, 60). In spite of the obvious economic impact of crop losses due to pests, governments generally have not emphasized improving plant protection as a means of increasing and ensuring adequate food security. A general trend exists of under-investment in plant protection extension, research, and training relative to other disciplines of agriculture (3).

To date, the largest efforts to develop IPM systems for crop pests have been through the CILSS (The Permanent Interstate Committee for Drought Control in nine West African Countries of the Sahel) Integrated Pest Management Project and U.S. Agency for International Development's (AID) Regional Food Crop Protection Project (RFCP). Both focused on pest problems of basic crops in the Sahel (the RFCP Project also included Cameroon and Guinea Bissau). Also, both projects served to increase attention to crop protection issues and improved Sahelian institutional capabilities in IPM (70). However, the CILSS IPM Project was unsuccessful in developing IPM packages for the RFCP Project to extend because the projects suffered management problems that reduced their effectiveness (70).

Improving the Use of Chemical Pesticides

Development assistance often has relied on chemical pesticides for quick "solutions" to pest problems but often has ignored long-term impacts (3). In some respects, pesticide problems in Africa and in other developing areas have come about because of an error in the transfer of technology. Modern pesticide technology developed by and for use in the developed world has been exported to developing countries without adequate attention to whether the institutional capacity existed to handle it

(2). These problems are exacerbated by industrialized nations' policies allowing export of unregistered and highly hazardous pesticides. Although some people have advocated banning export of such pesticides, this does not have the support of many exporting countries nor importing countries who desire to retain sovereignty over their choice of imports.

Pesticide use is encouraged also by subsidies that serve as incentives for farmers to use more than may actually be needed, discourage farmers from using alternative methods, and impede institutional efforts in IPM (58). In Senegal, 90 percent of all agricultural pesticides are distributed to growers free of charge by crop marketing boards and other agricultural agencies. The rate of pesticide subsidy in Ghana is nearly 70 percent (3).

Development assistance could take a longer term view that encourages sustainable, safer solutions to predictable problems. For instance, the Food and Agriculture Organization of the United Nations (FAO) and various locust control agencies could contribute by placing increased emphasis on early-warning systems for locusts and other migrant pests, thereby encouraging a preventative—rather than crisis-reaction—approach to controlling major pest outbreaks.

Recently developed guidelines within FAO, the World Bank, and AID hold promise for improving the safety of pesticide use in developing countries. The FAO Code provides voluntary guidelines for governments of exporting and importing nations on distribution and use of pesticides. The World Bank Guidelines prohibit use of highly toxic pesticides and unsafe pesticide practices in Bank-financed projects. AID's policy on pesticide assistance requires a risk-benefit evaluation of agricultural pesticides proposed for use in AID's development assistance projects. However, AID could strengthen its policy of encouraging the use of non-chemical methods and IPM systems. AID's present funding of pesticides in development projects could be reduced or eliminated in countries that lack proper infrastructure for handling the materials. It is too early to determine the impact of the FAO, World Bank, and AID guidelines, but they represent a step toward preventing pesticide abuse and should serve as an important reference for other donors and pesticide enforcement agencies in Africa.

IMPROVING ANIMAL HEALTH

Summary

Poor animal health is the most serious obstacle to improving livestock production in Sub-Saharan Africa. Three principal mechanisms are available to overcome constraints to animal health (75):

1. improve control of endemic diseases and parasites,
2. enhance nutrition to reduce susceptibility to disease and parasitism, and
3. use disease-resistant breeds and study the mechanisms and inheritance of disease resistance.

Progress in improving animal health necessarily involves all three approaches since nutritional status, exposure to disease, and genetic make-up all interact to determine how well an animal is able to function in a given environment. This section examines the role of veterinary support and improving animal nutrition in grazing and mixed crop/livestock systems. Disease resistance is covered in chapter 9.

Improved understanding and appreciation of traditional livestock systems have provided important insights for livestock development in Africa. Increasingly, research illustrates the value of indigenous livestock breeds and local practices. Development agencies are more cognizant of the multiple values African agriculturalists derive from livestock, and are more aware of the need to consider these various uses when promoting livestock development. Western livestock specialists are facing the fact that livestock development in Africa needs to be viewed from a perspective quite different from that to which they are accustomed:

> Because of the major focus (in industrialized countries) on meat or milk production, we look upon the thin, boney looking cattle arriving at slaughter markets in (developing countries) as having undergone gross mismanagement. However, when we recognize that the major strategy is to utilize animals for human subsistence, the emaciated animals entering the market can be viewed as having rendered valuable services rather well. The challenge for the developing countries is not one of shifting livestock to a meat/milk economy but rather working within traditional systems to increase overall efficiency of the total services rendered by the animals through such programs as health services (46, p. 13).

Veterinary Support

Veterinary medicine has made great advances over the last several decades. Mass drug production techniques have greatly reduced drug costs and many side effects have been reduced or eliminated (14). As the value of livestock relative to the cost of veterinary care continues to increase, the economic viability of investing in animal care has become increasingly attractive, even to low-resource farmers and herders. For the most part, however, veterinary services are highly subsidized by African governments in order to capitalize on economies of scale in mass immunization programs (14). Subsidies also help to increase national meat and milk production and therefore to lower consumer prices.

Veterinary support services were among the first livestock projects promoted in Sub-Saharan Africa some 60 years ago, and these types of projects still predominate. One problem caused by this heavy emphasis on veterinary work is that while most epidemic diseases are now largely controllable and livestock populations have increased as a result, other needed areas of technology (e.g., range management and animal husbandry) and institutional backup have lagged behind (14). Lack of effective disease surveillance and disease reporting systems, as well as a lack of adequate diagnostic laboratories also hamper progress in disease control (16).

Development assistance agencies to date have focused their animal disease control efforts on trypanosomiasis (48). Trypanosomiasis, transmitted by the tsetse fly, afflicts humans (sleeping sickness) and animals (Nagana). The tsetse fly is present in 37 African countries, infesting some 9 million hectares or 42 percent of the total land area. Thirteen countries[4] are almost completely infested (62). Altogether, some 45 million people are estimated to inhabit infested land. The U.N. Food and Agriculture Organization (FAO) estimates that presently infected areas might eventually support up to 120 million head of cattle (or the equivalent of other stock) if the disease were controlled (48).

Controlling trypanosomiasis by animal immunization is at present impossible and treatments have in many cases produced drug-resistant trypanosomes. Thus, for now the control of tsetse and trypanosomiasis will rely on a combination of other methods including ground and aerial spraying of insecticides, changing the tsetse's habitat through bush-clearing, disrupting the tsetse's reproductive cycles through the release of sterilized flies, and the use of baited traps to reduce populations (48,76). Increased attention is also being directed toward improved husbandry and management of animals that display some tolerance to typanosomiasis such as the N'Dama, Maturu, and Keteku breeds of cattle (16) (see ch. 10). This extremely dynamic and constantly changing livestock disease creates unique difficulties in efforts to implement and monitor elaborate control and eradication programs.

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[4] Benin, Central African Republic, Congo, Equatorial Guinea, Gabon, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Sierra Leone, Togo, and Zaire.

Some people are concerned, however, that an inordinate proportion of resources and funding have been focused on trypanosomiasis (16). While researchers generally agree that controlling trypanosomiasis would have major impacts on the potential for livestock development, many argue that development of a general vaccine to deal with this variation seems unlikely for some time because of the large number of strains present among the three African trypanosome species and their characteristic of changing forms in the bloodstream (16,59).

In the meantime, a number of other diseases that may be more easily controlled have received considerably less attention. Two such diseases are rinderpest and contagious bovine pleuro-pneumonia (CBPP). Vaccines for both exist, the former with a once-in-a-lifetime inoculation, the later providing one year immunity (so research on longer term protection is desirable). Other relatively neglected livestock diseases in Africa include East Coast Fever and other tick-borne diseases, foot-and-mouth disease, streptothricosis, African swine fever, and various diseases caused by internal parasites. Box 11-1 identifies major livestock diseases in Africa and the availability of control methods.

Breakthroughs in preventing and treating animal health problems have outpaced the ability to distribute the veterinary technology in Africa. African extension systems face numerous problems including a lack of adequate funds to get trained staff into the field to address clients' needs and a general lack of proven technologies that do not disrupt the delicate equilibrium of interacting environmental, economic, and social factors in African livestock systems (14). A further problem is how the lack of interaction between veterinarians and other livestock scientists has created a narrow focus for extension agents. Most agents are trained in veterinary sciences and are seldom able to provide support on improved range management or animal husbandry. The benefits of veterinary support could be enhanced if promoted in conjunction with improved nutrition and management (14,16).

Access to vaccine is fundamental to disease campaigns. A recent review of vaccine-producing facilities in Africa found that relatively minor investment in these facilities and rehabilitating their equipment could result in adequate production levels of rinderpest and CBPP vaccine for the region (30). Problems of inefficiency and improved quality control need to be addressed, however. Vaccine for poultry (e.g., Newcastle vaccination), can be more efficiently and cheaply obtained in international markets (14).

Animal Nutrition

Livestock malnutrition is considered by many to be the single most serious limitation to improved livestock production in Africa. Nutritional stress, compounded by intestinal parasites, is largely responsible for the high mortality (17 to 45 percent) recorded for calves, kids, and lambs in their first 3 months (14,45). Improving animal feed has thus become a major focus for African livestock development. This emphasis is reflected in staffing at the International Livestock Center for Africa (ILCA), where plant agronomists significantly outnumber animal scientists and veterinarians combined (46). Investigation of forage species, treatment of crop residues to increase digestibility, and improved storage qualities in forage are important areas being studied. Another promising avenue of investigation is providing supplemental fodder for small ruminants in mixed production systems (see ch. 10).

.Improving animal nutrition in Africa confronts the same serious problems as in cropping systems—resource-poor farmers and herders' severe constraints on access to exter-

Box 11-1.—State of the Art: Control of Major Livestock Diseases in Sub-Saharan Africa

Rinderpest: A virus affecting ruminants and occasionally swine. It has a high mortality and spreads rapidly. A reliable, once-in-a-lifetime, vaccine is available but could be improved by making it thermostable, thereby reducing cost and reliability problems associated with current cold storage requirements.

CBPP (Contagious bovine pleuro-pneumonia): A cattle disease caused by parasitic micro-organisms called mycoplasma. Immunity can be maintained for one year with vaccination but longer term protection is desirable. Treatment is also possible but generally not practical.

PPR (*Peste des petits ruminants*): A viral disease affecting small ruminants that can result in high mortality and is increasing in prevalence. A once-a-year inoculation with rinderpest vaccine has good results.

Anthrax, Blackleg, Pateurellosis: Available vaccines are adequate.

African swine fever: A complex disease precluding intensive swine production in many areas. No effective control exists except slaughter. Research on control methods is needed urgently.

Trypanosomiasis: No complete control exists. Because of the complexity of the pathogen, development of a vaccine has low probability in the next 10 to 20 years. Control of the vector (tsetse fly) through use of traps or vaccine-impregnated screens is most promising. Aerial spraying is expensive, clearance is seldom permanent, and may be environmentally harmful. Research on fly attractants, use of sterile male flies, and the search for tolerant cattle breeds deserves high priority.

Dermatophilosis (Cutaneous streptotrichosis): As yet this is an under-researched constraint to cattle production in the West African humid to sub-humid zone, and a major impediment to use of Zebu type cattle in infected areas. More investigation on control is needed.

Gastro-Intestinal Parasites: They probably cause the greatest losses among livestock in the region, especially in morbidity. Drugs for control are available but additional research is needed on integration into existing management systems.

Tick-borne Diseases: The International Laboratory for Research on Animal Diseases and the International Center for Insect Physiology and Ecology (both located in Kenya) have had promising results in vector control for East Coast Fever. Research is needed to see if this initial success can be extended to control vectors of piroplasmosis and heartwater in West Africa.

SOURCES: World Bank, Western African Projects Department, *West Africa Agricultural Research Review* (Washington, DC: The World Bank, February 1987); William M. Moulton, "Major Disease Deterrents to Improving the Sub-Saharan African Livestock Industry," J.R. Simpson and P. Evangelou (eds.), *Livestock Development in Sub-Saharan Africa: Constraints, Prospects, and Policy* (Boulder, CO: Westview Press, 1984), pp. 79-90.

nal inputs. The need to depend on resources internal to the system may be even more pronounced in animal agriculture, however. The greater isolation of grazing systems, particularly among pastoralists, necessitates a higher level of self-sufficiency. In mixed crop/livestock systems, animal rearing is undertaken as a secondary activity to crop farming, so resource-poor farmers are generally less willing to divert meager resources to animal improvements. Understanding these constraints has important lessons for research and development assistance.

> The principles underlying (the efficient use of crop residues and pastures in Africa) center on maximizing their utilization rather than on achieving an optimal nutritional status for each animal. The difference between these two contrasting concepts is important. The . . . key task is to use what is available in African smallholdings, rather than to seek the ideal feeds for African animals (4).

Problems of animal nutrition are quantitative and qualitative. Quantitative improvements can be achieved through proper stocking of rangelands, establishing improved pastures as complementary forage to native pastures, planting forage crops, promoting soil and water conservation practices, and through timely harvest and storage of crop residues (75). Improvements in quality involves ensuring nutritional adequacy of pastures, forages, and feed supplements and correcting deficiencies through pasture management, germplasm selection, and residue enhancement (75).

Seasonal fluctuations in the availability and nutritional adequacy of feed supplies are among the most serious nutritional problems for African livestock in pastoral and mixed crop/livestock systems. Shortfalls are most pronounced in the dry seasons in arid and semi-arid zones. It is during this period when competition for animal milk between calves and people becomes most pronounced. The consequence of this is low weaning weights and high morbidity for calves. Improving feed resources for calves and calving mothers can bring major improvements in calf survival rates. Finding ways to supplement feed during this period is critical to improving productivity and thus deserves high research priority.

Domestic ruminants such as cattle, camels, goats, and sheep must be able to obtain some minimum level of energy from the plant material they eat. These animals are not able to compensate for nutritionally poor forage by eating more, so access to quality forage is essential. The level of plant material or dry matter that an animal is able to mobilize for energy is called its digestibility or DIG—a function of the total digestible nutrients of the plant (46). For domestic ruminants, the required DIG value is approximately 45 percent. Only about 5 percent of the feed available on low-resource farms is typically of high nutritional content, i.e, with a DIG value of 55 percent or greater (46). Of the remainder about half has adequate nutritional range (DIG 40 to 45 percent) and half is less than adequate. Research to increase the feeding value of plants and byproducts by 5 to 10 percent thus could prove significant (46).

The principal mechanism for increasing digestibility is to provide the microbial organisms in the animal's digestive rumen track with an improved supply of nitrogen and other critical growth factors. This can be achieved by chemically treating crop residues (e.g., with anhydrous ammonia or urea), supplementing crop residues with more nitrogen-rich forage (e.g., *Trifolium*) or both (4,46). Although these approaches appear promising, more on-farm testing is needed to better assess socioeconomic feasibility under resource-poor conditions (76).

Low nitrogen levels in many African soils hinder both plant and animal productivity, so researchers have begun to focus attention on using forage legumes to enhance soil fertility and provide a protein supplement for livestock simultaneously. Some efforts are being directed to improving protein sources within grazing regions such as by planting nitrogen-fixing trees in conjuction with reforestation campaigns. Others are aimed at better extracting leaf protein from legumes (69). The major focus, however, is on more intensive agroforestry systems, such as using leguminous forage species as links between crop and livestock production (see ch. 10).

Various forms of animal confinement, such as maintaining animals in stalls or tethering them, are becoming increasingly prevalent in more populated, land-scarce regions of Africa. Stall feeding historically has not been a part of African agricultural systems, except in small enclaves such as the Mandara Mountain region of Northern Cameroon, on the slopes of Kilimanjaro in Tanzania, on the island of Ukaru in Lake Victoria, and on mixed-cropping dairy farms in Kenya and Rwanda. Another exception is the common rearing of small livestock in and around many urban areas throughout Africa (29). The primary constraint to animal confinement is that it is labor-intensive and thus it competes for labor also needed for growing crops. Confinement also tends to increase the incidence of animal health problems and mortality in the absence of adequate veterinary care.

Confinement offers some significant advantages, however. First, it is possible to regulate nutritional needs more carefully, assuming that sufficient fodder and feed-supplements are available. Second, manure can be collected, allowing it to be used more efficiently for fertilizer. Third, veterinary care is easier because the animals are contained (vaccinations and

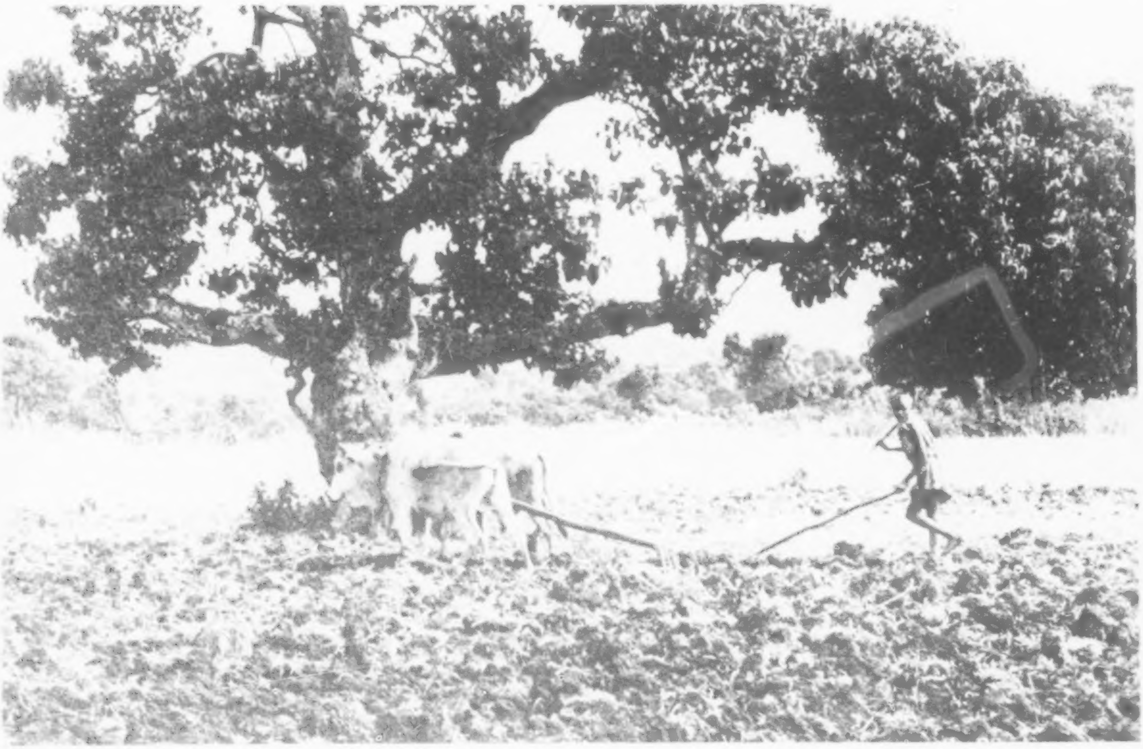


Photo credit: Kay Muldoon/The World Bank

Inadequate animal nutrition is the most serious limitation to improved livestock production in Africa. Livestock's fitness for animal traction is most important during the dry season when high quality food is in short supply.

many other veterinary services are made easier, but containment actually aggravates other problems, such as ticks). Fourth, animal feeding efficiency is increased due to reduction of energy expended for grazing. And last, confinement generally produces higher quality meat.

Potential Gains From Improved Animal Health

Improvements in animal health offer direct and indirect benefits for agricultural productivity (14). One direct benefit is reduced mortality. Given the high mortality rates common for African livestock (25 to 40 percent for young stock and 3 to 15 percent for older stock), the potential for significant improvement seems great. To illustrate, vaccination and dipping campaigns in two Nigerian villages recorded a 75-percent reduction in death rates of sheep and goats (35). In another case, veterinary packages for goat care brought economic returns of at least 20 percent (76). High returns are also reported for the rinderpest campaigns and efforts to combat foot-and-mouth disease (14). Although these returns on investment appear attractive, research is still needed on the ability and willingness of resource-poor agriculturalists to take advantage of these services.

Improved animal health care also brings indirect benefits. As noted above, shortfalls in feed during parts of the year and competition between humans and calves for milk supplies causes high levels of pre-weaning mortality in African livestock. By improving calf nutrition during this period, not only is mortality reduced, but indirect benefits are achieved such as earlier sexual maturity of livestock, increased mature body weight, and increased efficiency in overall feed use (5,14).

The prospect of controlling tsetse fly or at least expanding stock of trypano-tolerant livestock could have major impact on crop and livestock production in Africa. Many currently infested areas are among the most arable and they potentially could support sizable human populations. Increasing population densities in these regions can, in turn, help control reinfestation. Some researchers note, for example, that as land is converted to cultivation, shade cover is decreased and the habitat becomes less suitable for tsetse flies, which require shade (57).

Problems and Approaches

Much of Africa may be witnessing a deterioration in animal health services at a time when greater—not less—support is needed. It is unlikely that governments will be able to provide significant increase in funding for livestock development. The challenge for development efforts, therefore, must focus on making more effective use of existing resources.

Incorporating Sustainability in Eradication Program Planning

Considerable resources and energy have been directed to livestock disease eradication programs in Africa, particularly rinderpest and trypanosomiasis. In both cases, however, the area of infestation has actually increased in recent years. Headway has been made in particular regions, only to be lost because necessary provisions to contain the disease could not be sustained.

Serious concerns exist over the ability of African governments to sustain disease eradication programs after donor-supported mass inoculation campaigns are completed and the responsibilities, including costs, are transfered to national governments. The recent resurgence of rinderpest in Africa illustrates the problem: after a successful disease control campaign in the 1960s and 1970s, a serious resurgence has occurred because poorer African countries were unable to continue to vaccinate young stock once donor funding was discontinued (figure 11-1) (48). This suggests that criteria regarding sustainability must be incorporated in program planning, especially in light of mounting interest in another major rinderpest eradication program.

It is also evident that efforts to clear areas of tsetse fly infestation will continue as a major focus of livestock development work (66). Here too, provisions should be made to ensure greater sustainability. Attention to long-term land-use planning is essential if success is to be achieved and funds not wasted (57). Land should be capable of supporting intensive land use, since establishing permanent agriculture in an area is a first line of defense against reinfestation. This may require establishing adequate support services and infrastructure, as well as policy interventions. Further, the ability of farmers to invest in animal husbandry and management—particularly in animals that display some trypano-tolerance—may be as important as those technologies for directly controlling tsetse flies (e.g., traps and spraying) or trypanosomes (e.g., trypanocidal drugs) (16).

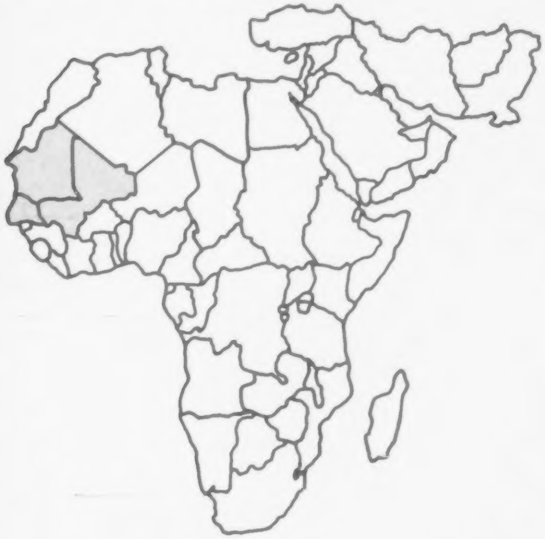
Large-scale efforts to control trypanosomiasis in a region must also address their sustainability, for example, by making an assessment of potential adverse impacts. The FAO commission on African Animal Trypanosomiasis recommends, for example, that tsetse fly control or eradication be supported only in conjuction with land-use planning that accounts for increases in the spontaneous settlement that would undoubtedly follow a successful campaign (48).

Promoting a More Integrated Approach to Livestock Development

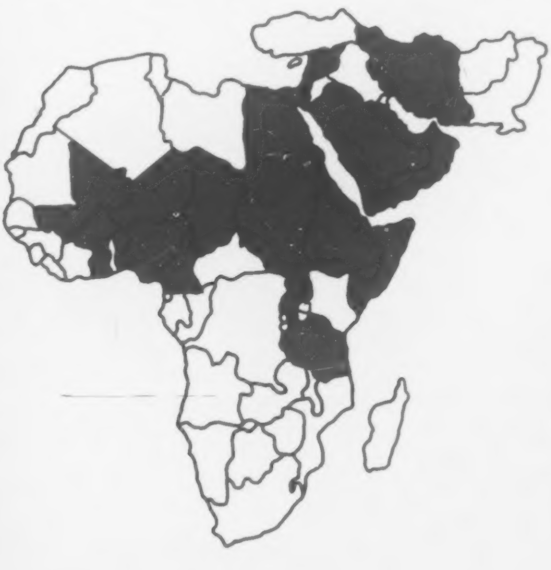
Livestock development work has been approached, for the most part, as single sector/single technology interventions. Interventions have generally failed to be examined for their impacts on the broader production system, potential adverse effects have been discounted and possible complementarity of coordinating activities among sectors has not been investigated. In looking at the various obstacles to

Figure 11-1.—The Resurgence of Rindepest in Africa and the Near East

The situation between 1976-79
(after termination of the JP 15 Campaign)



The situation after 1979 to date



■ Countries reporting rinderpest

SOURCE: Della McMillan, "Government Assisted Land Settlement: Status and Potential in African Low-Resource Agriculture," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).

livestock development, what at first may seem an obvious solution, may in fact exacerbate problems (18). For example, solving livestock watering problems in arid and semi-arid regions by drilling boreholes seemed an obvious solution, but experience has shown otherwise because severe overgrazing occurred near wells. Similarly, veterinary interventions to address problems of high mortality in pastoralist herds have also tended to lead to serious overgrazing and, in many cases, have worsened existing problems.

> Programs are initiated without coordination. They are in the hands of technical experts, each of whom is concerned only with his or her own area of expertise. There is no effort to relate the actions taken to the full cycle of activities necessarily involved . . . What is needed is a coordinated approach. This means that such technical matters as disease control, land improvement, and marketing operations are to be developed in a concerted, integrated fashion. It also means that the legitimate interests and aims of the pastoralists, including their use of livestock as factors in their social relations, are taken into account (18).

A number of technologies able to enhance animal health under low-resource conditions have been identified. In humid and subhumid regions, cut-and-carry fodder operations seems particularly promising for more intensive systems, such as livestock/agroforestry systems and intensive forage gardens. In more arid regions, access to dry-season fodder supplements could significantly improve calf survival rates. Various forms of pasture and fodder improvements or improved conservation of crop residues could meet these needs (31, 38). Cultivating the potential of these various technologies, however, will require greater collaborative work than currently exists among plant and animal scientists, as well as other social scientists.

The importance of crop residues as supplemental feed has particular implications for crop breeders who, often divorced from the needs of the livestock subsector, tend to ignore the importance of crop residues to resource-poor farmers. Considerable variation exists in the digestibility of crop residues. Technology to supplement or treat crop residues for increased digestibility is an important area for collaborative research. Increased attention should now be directed to on-farm research and testing; this will also require supportive socioeconomic analysis to evaluate technologies' impacts and adoption under farmers and herders' conditions.

Adjusting Imbalances in Technical Support Services

A number of imbalances in African technical support services have been identified that, if corrected, could provide more effective use of scarce resources devoted to improving animal health—especially among resource-poor farmers and herders. These include excesses in funds devoted to veterinary support v. other areas of animal health; in research and extension budgets devoted to salaries v. operations; and in soliciting students for livestock extension services from farming and urban backgrounds v. from pastoralist communities.

Veterinarians comprise an estimated 70 percent of all African professional livestock workers and have been successful in setting research priorities for African livestock development. Major advances have been made in controlling most epidemic livestock diseases as a result. Research for other animal health areas, such as animal nutrition, as well as related disciplines of range management and animal husbandry have suffered relative neglect. Advances in these neglected areas are essential for resolving the most important constraints now confronting sustainable livestock development in Africa. This suggests that a more balanced allocation of research activities could be promoted.

Concerns also exist over the increasing proportion of livestock services budgets being directed toward staff salaries. Although a general underinvestment in scientific staff is widely recognized, more specific concerns are expressed due to the relative emphasis on staff v. operating funds, and the ineffectual services that can result. One reason for this is that in many African countries vocational school graduates are basically guaranteed a civil service position. Because operating budgets are stagnant or declining, the increasing number of personnel have little money to support research or buy equipment (14). For the most part, staff are underemployed except for the few months during vaccination campaigns. Also, staff are heavily restricted in their ability to engage in field work and research, perhaps reflecting a more serious problem.

Another imbalance in livestock support services stems from the relatively few pastoralists in such technical support positions. Students from pastoral communities are less likely to be solicited to become veterinary agents than students from farm or urban backgrounds (14). Important benefits may be derived from increasing training among members of pastoral communities because of their greater familiarity with livestock problems and management practices. Also, greater confidence may emerge between veterinary agents and the people they serve when veterinarians' backgrounds reflect their clients'.

Providing pastoralists with veterinary support still presents unique challenges. These include accommodating the needs of a transient people and finding trained veterinarians willing to live and practice in those conditions. One solution currently being investigated is providing veterinary support via a pastoralist with some basic training and access to supplies, but who will live and operate within the pastoral community. Experience with grassroots veterinarians—or paravets, as they are sometimes called—is still too new to judge their effectiveness, but initial results are promising. Experience in Niger and the Central African Republic suggests that frequent contact with government services and the existence of supportive institutional structures (e.g., pastoralist associations) tend to increase their effectiveness (14).

Supporting Regional Cooperation

Increased cooperation in research seems essential in a region where a critical mass of qualified researchers per country is often lacking. Establishing research networks thus becomes very important. In addition to being able to link individual scientists, networks represent a resource for national program development through coordination, technical backstopping, training and printing facilities, and information dissemination (4). The proliferation of research networks dealing with livestock and crop/livestock issues and the increased funding being devoted to these groups is a promising development.

Production of animal vaccine is another area where significant benefits may be derived from regional cooperation. For example, benefits may be derived from designating particular facilities for primary responsibility for particular vaccines. This would reduce the need for individual facilities to produce smaller amounts of many different products.

POST-HARVEST TECHNOLOGIES[5]

Summary

Post-harvest crop losses significantly reduce the food and income available to resource-poor agriculturalists in Africa. It is difficult to estimate food losses with precision; they are location- and season-specific to a degree that makes the concept of "average levels of loss" almost meaningless (53). Previous high estimates for overall food losses (e.g., at least 20 percent) are no longer accepted by most scientists, although losses can exceed this level in specific cases (20).

Post-harvest processing typically demands long, tedious hours of labor. While African women are active in field production of crops and livestock—responsible for 50 to 70 percent of planting, weeding, hoeing, and harvesting of crops, as well as domestic animal care—post-harvest activities are almost entirely their domain. African women are typically responsible for 80 to 90 percent of the transport of crop from the fields and their subsequent storage and processing, as well 60 percent of the marketing. These activities are balanced around other responsibilities for collecting water and fuel, cooking, and family care for which they are almost entirely responsible. Efforts to enhance post-harvest technology thus should primarily benefit, and specifically evaluate impacts on, African women. More efficient technologies can contribute to free time that can be spent on farming or family activities, or other enterprises (61).

Numerous post-harvest technologies exist for each of the dozen or so major African crops, livestock, and fish. Socioeconomic and technical factors influence the selection of a particular technology, including the size of the farming enterprise, the reliability of the harvest, labor availability, food needs, and income-generation potential (61). OTA has only dealt with a small illustrative subset of promising post-harvest technologies for drying, storing, and processing foods, and in the cases of rice and maize, threshing or shelling for separating the grain from the rest of the plant.

No single machine or new practice will drastically improve the post-harvest operations of African farmers, but a large number of relatively simple technologies do exist that have the potential to improve the various post-harvest processes. Several of these improved technologies have been successful in reducing labor demands and in making operations more efficient. These improvements face the best likelihood of success if they are adapted from

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[5] This material is based primarily on the OTA contractor report prepared by the Tropical Development and Research Institute, London, U.K., (app. A).

proven, traditional techniques and if they take into consideration the primary role women play in African agriculture.

Development assistance to improve post-harvest technologies can be most effective by using an integrated approach that considers the entire production system and the interactions of various farming activities. Assistance can then be directed to the greatest problems, which will differ among farming systems. Such a location-specific approach also will enable assistance to change, as necessary, to match the changes that accompany development.

Opportunities for Improvement

Threshing and Shelling

Rice, an important crop in humid regions, is still harvested by hand on most low-resource farms and threshing is done by trampling or hitting the rice-bearing straw against a hard surface—both inexpensive techniques, but labor-intensive and wasteful. Small, pedal-operated rotary threshers are in use in West Africa. This technique is faster, reduces waste because stalks can be refed to separate more grain, and allows the hands to remain free to feed the thresher. But to illustrate the importance of considering local conditions, these threshers may prove unsuitable in certain areas of West Africa where custom forbids women to sit astride. Where draft animals are available they can be used to power a simple thresher that increases output considerably compared with traditional methods and has the advantage of not requiring the rice stalks to be collected into bundles (61).

Small quantities of maize, another African staple, are traditionally shelled by hand—a process that is laborious, tedious, but efficient because little grain is damaged. Larger quantities are shelled by placing the cobs in a sack and beating this with a stick. However, some hand-held shellers are now available such as a wooden one developed by the Tropical Development and Research Institute (TDRI) (61). This tool is simple, inexpensive, and made from local materials, but it is tiring to use extensively and only shells cobs of a standard size. Small rotary shellers seem suitable for resource-poor farmers and are being introduced into rural areas of Kenya by the United Nations International Children's Emergency Fund (UNICEF). Surveys show, however, that unless they have large amounts of maize to shell, farmers prefer traditional methods because few kernels are crushed. Simple machines to speed threshing and shelling would seem opportune, but the social consequences (e.g., reduced employment for women) must also be considered (61).

Drying and Storage

Food must be dried properly before storage to prevent deterioration, inhibit grain germination, limit the growth of fungi and bacteria, and reduce insect infestations. Over-dried crops are subject to breakage, discoloration, scorching, and reduced nutritional value. Many drying methods are available and the choice of method depends on several factors such as climate, quantity, intended final use of the food product, and the availability of fuel. For most staple foods, the basic methods available to resource-poor farmers are sun and air drying. Some artificial drying is necessary when crops are harvested during the wet season.

Traditionally, grains such as rice, millet, and shelled maize are simply spread on the ground and left to dry in the sun. One straight-forward way to speed this process is to place the grain on a black plastic sheet to increase the air temperature. This process also is effective for root crops such as cassava; in fact, cassava drying time can be reduced 25 percent by using a black plastic base. Where maize matures during wet periods, such as in the humid areas of West Africa, rapid drying is necessary to prevent spoilage. Drying cribs provide shelter from the rain and allow ventilation through open sides (61).

As farmers grow more improved, high-yielding varieties of maize that mature when the conditions for air and sun drying are inadequate, some artificial drying becomes essential. One simple dryer consists of a cylindrical clay structure with a thatched roof and a raised floor. Fuel is burned beneath in a firing chamber; air is drawn in, heated, and rises through the grain. Farmers' acceptance of this technology has been slow, however, because the dryer is hard to install and use. Other alternatives are in use, but a need still exists for low-cost dryers that can be built from locally available materials. Solar dryers are another option. The National Council for Science and Technology in Kenya has developed an improved solar dryer that provides equal drying on all sides without overdrying. The dryer is made locally of black-painted wood, covered with polyethylene, and has a metal drying chamber. Although solar dryers are inexpensive to operate, they do not operate effectively during the rainy season (61).

Once a crop has been dried to a suitable moisture level, it must be stored. Storage must protect crops from rain, theft, and attack by fungi, insects, and rodents. Cassava presents particular storage problems because it deteriorates within a few days of being dug from the ground. Traditional cassava storage methods include reburial, coating with mud, placing under water, or the daily watering of heaps of cassava roots. An improved approach is packing freshly harvested roots in boxes of damp sawdust, which can be effective for 1 to 2 months.

Traditional approaches for storing grains in Africa are often ingenious in their design and use of local materials (27,41,55,63). Generally, storage areas are built from mud, plant material, stones, or some combination of these. They commonly have thatched roofs and are raised off the ground. In humid areas where the structures combine drying and storage functions, they are more open to allow ventilation (e.g., open-sided cribs). Since rainfall patterns and harvests tend to be more reliable in Africa's humid regions than in its drier regions, storage facilities tend to be smaller, holding perhaps a 1-year supply of food. By contrast, in semiarid areas where harvests are far less reliable, storage granaries are commonly large, substantial mud structures capable of holding 2 or more tons of grain for up to 5 years. Sealed, underground pits are sometimes used. Because dried grain is vulnerable to insects and rodents, farmers sometimes mix sand, limestone, or other abrasive minerals with the grain. This traditional method provides a relatively effective barrier because it affects the insect's surface in such a way as to cause subsequent desiccation of the pest. Mixing selected ashes, herbs, or dried animal dung also can protect stored produce against insect attack. Seeds of the Neem tree, which act as natural insecticides, have also been added to stored grain to repel insects (61).

Traditional methods of insect control in storage are rarely as effective as modern synthetic insecticides and fumigants, although they are less expensive and safer. Insecticides are now widely available in most countries and in some cases represent a cost-effective means of protecting stored produce. Training farmers to use these products safely and arranging for reliable supplies presents a challenge to extension services, however (61).

Processing

Processed grains and other staple foods make up one of the most important parts of the diet of most low-resource farmers. Processing is the essential step of readying crops and other foods for consumption, and it usually involves several slow, laborious steps. Food processing in almost all cases is the responsibility of women. Many opportunities to improve processing exist, with most focusing on reducing the labor involved. The following discussion gives examples of these opportunities for different crops and commodities.

Cereals.—Traditional milling of sorghum, for instance, involves soaking the grain to loosen the bran and then pounding it in a mortar to remove the bran. Sorghum grain is usually processed into a porridge or partially fermented flat bread. These traditional foods take a long time to prepare and they are losing popularity with urban populations. Sorghum, however, grows

Photo credit: B. Imevbore/U.N. Food and Agriculture Organization

Low-resource farmers use a variety of inexpensive and simple methods to store harvested grain. Traditional granaries, such as these made in Nigeria from reed or mud, are relatively effective but can be improved.

well in semi-arid regions and is drought resistant so new processing techniques that could produce more marketable foods and encourage wider acceptance could relieve some dependency on imported food. TDRI, together with the Kenya Industrial Research and Development Institute (KIRDI), is developing "instant" foods from sorghum and promoting these as substitutes for rice. Also, a mechanized milling method known as dry abrasion has been introduced into villages in Botswana by the Canadian International Development Research Center (IDRC). Once trained to use this mill, a farmer can save several hours of labor each week.

Maize is traditionally milled with a pestle and mortar, sometimes after soaking a few days so fermentation can occur. The equipment used is inexpensive, but the process is time and labor consuming. Various types of hand mills are available, but rural women are increasingly making use of community mills.

Small amounts of rice can be processed for daily use, but the bulk of the crop is stored in an unprocessed form so that it is less vulnerable to insects. Processing involves several stages, including soaking, parboiling, drying, hulling, and winnowing. Each step is time-consuming and has potential to be made more efficient through new techniques and equipment. For instance, parboiling is done to make hulling easier and it reduces the number of broken grains because the husk is split during heating and the kernel is strengthened. However, three tedious steps are involved: soaking the grain, heating it until it cracks, then drying it in the sun. In addition, rice prepared this way commonly has an unpleasant odor. The traditional method of winnowing is to toss the rice kernels and separated husks into the air from a flat wooden tray. The kernels fall back to the tray first while the lighter husks catch in the breeze and fall to the ground. Improved methods are being developed for both parboiling and winnowing. For example, hand-operated winnowers—such as one that consists of a vertical drum with a fan at one end—can be inexpensive and easy to build. A new method of parboiling is also being developed which is faster and does not result in the unpleasant smell (61).

Legumes.—Legume processing can be particularly demanding. The traditional method of hulling is to soak the legumes or mix them with oil, sun-dry them, and pound them in a pestle and mortar. The husks are then winnowed off. Small hand or power-operated hullers are available, but these often split the bean. Legumes are usually soaked overnight and then cooked for 1 to 4 hours, a process that is slow and results in the loss of valuable nutrients. Some precooked legumes—legumes that have been flaked, pressure cooked, and dehydrated—are being developed but the level of technology may be beyond the reach and access of resource-poor farmers.

One particularly important cash crop for resource-poor farmers is the groundnut—or peanut. Unlike other legumes, they do not have a hard husk. A wooden, hand-operated decorticator, developed by UNICEF in Kenya, is claimed to be three times more efficient than traditional hand methods for removing groundnut shells.

Cassava.—Cassava is a root crop and important staple that is processed into a variety of products according to local traditions and needs. Processing cassava is one of the most time-consuming and strenuous tasks faced by African women, and traditional methods can take several days to complete. The main products are chips, flour, and gari. Gari is becoming increasingly popular in some West African countries (e.g., Ghana) because of shortages of other foods.

To prepare cassava, it is first soaked a few days to reduce the cyanide content of the roots. Then the root is peeled, chopped into small pieces, and sun-dried. Chips are produced after drying for 3 to 10 days. The chips are pounded in a mortar to make flour. Gari preparation is also lengthy but, once prepared, it is easy to cook and keeps well for several months. Peeled root is washed and grated, then allowed to ferment. Simultaneously, water is extracted either by placing the mixture in bags under heavy weights or some other pressure system. Next, the fermented cassava mixture is sieved and roasted.

Techniques are being developed to speed and ease these various steps. Hand or pedal-operated graters are available now. Improved presses, too, are under development. Any modification to traditional methods, however, must be careful to result in a comparable cyanide reduction.

Oil Seeds.—Vegetable oils are an important commodity and are often in short supply. Palm oil, in particular, is a major income source for rural women in the humid areas. While palm fruits are harvested by men, oil processing is a woman's task. First, the fruits are boiled for 5 to 10 hours in an iron pot. The oily fibers are then separated from the rest of the seed by either pounding in a mortar or trampling in a pit. These methods are slow and laborious. In traditional processing, water is added during fiber separation and the oil is scooped and sieved from the mixture of fibers, kernels, and water. Then the oil is boiled in drums and left to cool, where any remaining vegetable debris sinks while the oil floats and can be skimmed off.

Several advances have been made in oil processing. Sterilizers, small boilers for steaming larger quantities of seeds in shorter time, have been developed. A palm-pounding machine also exists. Several types of screw and hydraulic presses have been designed to make the final stage of oil extraction easier and less time-consuming, but again, such techniques are not in widespread use.

Coconut oil, sunflower oil, and other seed oils are also important in various regions and are similarly difficult to process. Simple improvements in graters and presses can increase output. For example, shea nuts are a locally important source of shea-nut butter, an edible fat that provides income for rural women. Traditional methods of producing the butter result in about 25 percent fat. A hand press developed by the German Appropriate Technology Exchange (GATE) results in high-fat butter, reduces the time involved, and cuts fuel requirements. Although it is expensive to buy initially, the press is estimated to pay for itself in 2 years because of the extra income it generates.

Milk.—Milk products are highly valued by herders and farmers. Herders use milk and milk products as barter for food grain. Surveys have revealed many traditional systems of milk preservation, principally in the form of butter, ghee, or other fermented products (47).

The International Livestock Centre for Africa (ILCA) recently organized a dairy technology unit, whose focus is to research low-cost means of milk preservation (36). Working in the highlands of Ethiopia, the ILCA group has developed an internal agitator fitted to the traditional regional clay milk churn that cuts churning time in half and has increased butter recovery from 75 to 92 percent. The program is also promoting the use of a locally producible wooden press for making cheese, including Queso Blanco, Halloumi, and cottage cheese (36). More efficient cheesemaking is also resulting from improved locally constucted evaporation coolers. As a result of these promising technologies, 13 countries have begun to direct attention to promoting similar improvements in milk preservation (47).

Fisheries.—Other particularly important food sources in many countries are derived from marine and inland fisheries. Major coastal fisheries are found in West Africa, Mozambique, and Tanzania, and inland fisheries are important around Lakes Chad, Victoria, and Malawi. The inland delta of the Niger River in Mali is also important because seasonal flooding supports a large population of migrant fishers.

Fish is a highly perishable commodity and heavy losses occur at every stage of the postharvest chain. Losses occur during handling on boats and after landing; from blowflies during drying and beetles during storage; and during smoking, packaging, and transport because of crumbling and spoilage. Much of the fish caught is sold immediately, but a significant portion is dried or otherwise preserved, especially where it is transported long distances. For migrant fishermen in Mali, for instance, 3 to 4 months elapse between the fish catch and consumption. As much as 50 percent of the fish processed can be lost.

The most common methods of fish processing are air and sun drying, salting, and smoke drying. The traditional approach to drying is simply to spread the fish on straw on the beach and leave them in the sun. One improvement is the use of simple racks that raise the fish off the ground and improve airflow around the fish. Racks can be built from local materials that are cheap and effective. Another potential improvement underway is the development of solar driers.

Salt drying, on the other hand, has the advantage of not only drying the fish, but preventing microbiological spoilage. It is usually carried out simply by sprinkling dry salt between stacked layers of split fish or immersing the fish in brine.

Smoke drying is widely used in West Africa and is traditionally carried out over a grid of fire or in mud, wood, or oil drum ovens. The heat not only dries the fish, but reduces blowfly attack. Blowflies are a serious threat to fisheries, particularly in the wet season when drying is slow. In Senegal in 1984, one-third of the fish catch was lost to blowfly infestation. Phenolic compounds in the smoke that inhibit bacterial action may also be deposited on the surface of the fish. While this approach is cheap, it requires large amounts of firewood, an increasingly scarce resource. Many different improved ovens are being introduced, such as the Chorker fish smoker that FAO introduced in

Ghana. This smoker has a large capacity, is easy to operate, reduces smoking time, and is inexpensive to build, although the design requires skilled workers (box 11-2).

Energy Sources.—One of the critical needs of the resource-poor farmer is fuelwood and other sources of energy for processing food. Fuelwood is becoming scarce in many parts of Africa. Reforestation efforts such as the country-wide tree planting initiative carried out by the Kenyan National Council of Women in 1977 are long-term solutions. Ways to meet needs more immediately include:

- Briquetting, where cellulosic residues such as rice husks or groundnut shells can be pressed into briquettes and burned. However, any development of this type of alternative energy source should be careful not to create problems with soil productivity and conservation due to removal of residues that otherwise would contribute to soil organic matter.
- Solar energy, too, offers an alternative although its role may be small. Solar cookers have proven relatively unsuccessful, in part because of the conflict with the local custom of cooking in the evening after the sun has gone down, and in part because they require direct sunlight and must be constantly adjusted as the sun moves. Solar driers, although not yet used on any significant scale, may prove more efficient.
- Improved cook stoves and post-harvest technologies that use fuelwood more efficiently (box 11-3) (8,10,28).

Potential

No single machine or new practice will drastically improve the post-harvest operations of African farmers, herders, and fishers, but a large number of relatively simple techniques do have the potential to make myriad small improvements. The impact of technologies can be enhanced if their development is based on an understanding of the entire production cycle. Fishing illustrates this point. As the capacity for fish processing is increased by improved ovens, more fish have to be supplied regularly to make the ovens economically efficient. Thus, improved fish catches are required, which requires improvements in boats, nets, and other gear. Boats could be fitted with engines, but their high fuel consumption and need for maintenance sometimes is not suitable for resource-poor agriculturalists. At the other end of the post-harvest chain, improved methods of packaging and marketing would similarly be needed.

The contribution of improved post-harvest technologies can be enhanced by focusing increased attention on African women (7,34,52). Most development programs in the past were directed toward men. Donor agencies and African governments are recognizing the necessity of assisting women because if the technology does not fit with women's many duties, it stands little chance of success.

Problems and Approaches

One of the obstacles that has hindered the development of post-harvest technologies for resource-poor agriculturalists is the low priority that this subject has received from development assistance agencies. Assistance typically has emphasized improvements in production; and the female-dominated post-production side of agriculture has lacked a vocal constituency. Furthermore, food losses at the farm level, as compared to commercial level, most likely are not as high as previously believed, and may actually be acceptable to the farmer or fisher. Development agencies may find it more rewarding to measure success in terms of reducing women's drudgery, rather than quantitatively measuring reductions in lost food.

The growing awareness in the development community and among African leaders of the need to find more effective ways of ensuring that assistance reaches women, offers hope that priorities are becoming more balanced. However, women still are underrepresented in extension service positions and at higher levels in the development assistance community.

A common feature of development failures has been the inappropriateness of introduced technologies. Not surprisingly, traditional

Box 11-2.—Women Invent New Technology for Smoking Fish

In Africa, as in other hot, humid zones, it is difficult to preserve fish products since fresh fish deteriorates rapidly and cannot be transported immediately to centers of consumption. This causes significant losses and reduces the amount of animal protein, already scarce, that reaches the local population. Hence, the importance of the chorkor, an oven for smoking fish named for the Ghanian village where it was invented in 1970. It was developed by local women with the assistance of a small project directed by the U.N. Food and Agriculture Organization (FAO) and the Food Research Institute in Accra, Ghana.

The chorkor is an improved version of the traditional cylindrical clay ovens that African women use for smoking fish. Although the traditional ovens still predominate, they are not very efficient. The women who use them work an average of 5 hours a day to obtain only 10 to 20 kilos of poor-quality smoked fish and they breathe in a large quantity of smoke in the process. Furthermore, the traditional ovens use enormous amounts of firewood, which is expensive in many African countries.

The women of Chorkor, aware of these problems, decided to modify the traditional cylindrical oven. A modified rectangular oven can be built of clay (which can be coated with a layer of cement to keep off rain), with sundried bricks, or with cement blocks mortared, like the bricks, with a mixture of sand and cement. It uses grills made of inexpensive wire netting and wood frames. The wooden frames allow 15 layers of fish to be dried at once (compared to 2 to 3 layers in the traditional ovens), and can be arranged to form a chimney to facilitate circulation of heat and smoke. The oven has two parts, divided by a partition, which can be used together or separately. This permits smoking fewer fish, if desired, and storing already-smoked fish in the section not in use.

The advantages of this oven over the traditional ones are great. It can be built in 5 days fairly inexpensively; it lasts longer (if the trays are built well and oiled regularly, and the frames kept from burning and protected from the elements, they can last up to 3 years, and a well-made oven can last up to 8 years); it can dry 240 kg of fish at one time (as compared to only 20 kg with the old system); and it gives a much more uniform and better-quality product. Moreover, it uses one-tenth the amount of wood that traditional ovens use, does not fill the eyes and lungs of the workers with smoke, and takes much less time and effort to use.

It is not surprising that the chorkor has been enthusiastically received, especially considering that the inhabitants of the West Coast of Africa prefer smoked fish to fish dried in the sun or salted. Smoked fish has a milder flavor, but since it has a higher moisture content, it spoils more easily if it has not been preserved properly as happens frequently with traditional ovens. With the chorkor system, the smoked fish lasts up to 9 months because the chimney formed by the trays allows more uniform penetration of smoke and heat. The chorkor is, consequently, not only an efficient innovation but also a socially useful technology, as much for the women who use the ovens as for the consumers.

Although it is still not well-known outside its region of origin, the chorkor oven is spreading with the help of FAO and UNICEF to Guinea, Togo, Benin, and Guinea-Bissau. In Guinea, for example, 300 women are forming a cooperative for preserving fish with the chorkor and for marketing what they produce. Togo will install 10 chorkors in strategic locations on the coast, teach the Togolese women how to take advantage of the new method, and give them technical advice on construction of the ovens; some Togolese women will go to Ghana to learn how it works. Guinea-Bissau hopes to spread the use of the chorkor to all the islands of the Bijagoz archipelago.

It is clear that the local costs of the raw materials for the construction of the chorkor oven will vary from country to country. The same is true of customs, tastes, and climatic conditions, needs of the local rural and urban populations, traditions regarding the use of fish, and the fish species that can be smoked. Obviously care must be taken in spreading use of the chorkor oven. But it is equally evident that the women of Ghana have made an important contribution to the development of appropriate technologies.

SOURCE: Guillermo Almeyra, "Women Invent New Technology for Smoking Fish," *Ceres*, vol. 20, No. 1, January/February 1987, pp. 5-7.

Box 11-3.—Improved Charcoal Stoves

Most stove programs in Africa have had little success, distributing at best 5,000 to 8,000 stoves. Many of the designs were too expensive, ill-adapted to traditional cooking or heating requirements, or required materials and skills that often were unavailable. An important breakthrough in fuel-efficient stoves came with the U.S. AID-funded Kenya Renewable Energy Development Project, launched in 1982. By the end of 1985 the project had given birth to a new industry whose main producers alone had sold 110,000 improved charcoal stoves at a profit.

The new stove is a modification of an existing one called a "jiko." In contrast to the jiko, the improved stove is about 50 percent more fuel efficient; it costs 65 to 100 Kenyan shillings, but lasts longer than the old one which costs 60 shillings. For the average Nairobi family spending 170 shillings a month on charcoal, the new stove pays for itself within 8 weeks.

There was a high level of local participation in the design. Scrap metal artisans were consulted to make manufacturing easy. The stove is constructed of scrap metal, with an insulating ceramic liner, a built-in grate in the top half, and an ash chamber in the bottom. Prototypes were test marketed in 600 households to make sure they were acceptable.

The Kenyan approach has potential in countries where fuelwood is marketed and is expensive. For the poor and scattered rural populations that comprise much of Africa, a different approach is needed. The improved stove developed by the Burkina Energy Institute, for example, is basically a shielded version of the traditional three-stone stove. The improvement is a circular shield built of clay, dung, millet chaff, and water that goes around three-stones that act as pot rests. The stove can be built in half a day to fit any desired pot size, and requires little, if any, cash. Fuel savings range between 35 and 70 percent. Most women recoup the investment of a day's labor within 1 or 2 weeks. The low-cost, high benefit, and rapid-dissemination method have brought some 85,000 improved three-stone stoves into use.

SOURCE: Paul Harrison, *The Greening of Africa: Breaking Through the Battle for Land and Food* (Toronto: Paladin Grafton Books, 1979), pp. 205-220.

methods have not been abandoned by farmers, herders, and fishers until an improved technology has clearly been shown to be an effective improvement and has few consequent disadvantages. The most successful technologies have been those based on, or improvements of, traditional practices. This recognizes that traditional practices are often well-adapted to existing conditions and are already proven to be appropriate and acceptable to the adopters.

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Chapter 12

Epilogue

CONTENTS

Page

U.S. Foreign Policy Interests in Africa 287
The Effects of Support for African Farmers on U.S. Agriculture 289
Conclusion 292
Chapter 12 References 293

Chapter 12
Epilogue

The decision by U.S. policymakers to assist resource-poor agriculturalists in Africa is one that will not be made in isolation. Instead, it will be made in conjunction with the broader objectives and goals of U.S. foreign assistance. Congressional decisionmaking is affected by these broader concerns. Different regions and different interest groups compete for foreign aid dollars. Congress' decision to provide funds for one purpose may reduce the money available for others. Cuts in domestic spending may necessitate additional changes in foreign assistance. Thus, any decisions Congress makes to support a resource-enhancing approach must consider how this element fits into the nation's underlying rationale for foreign assistance.

Two broad policy questions are raised as a result of the congressional committees' requests for this study[1]. First, the committees noted that the United States assists African farmers and herders for humanitarian, economic, and political reasons. But the relative importance of these different motives has shifted and the role of development assistance in this context is increasingly unclear (9).

Second, one committee specifically asked how U.S. support for African and global agricultural development affects U.S. farmers. This question echoes recent legislation, supported by various farm groups, to restrict U.S. bilateral and multilateral assistance promoting commodities also exported by U.S. farmers. The question has generated considerable controversy, especially given the problems faced by American farmers in the 1980s, and it deserves clear evaluation.

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[1] House Select Committee on Hunger; House Foreign Affairs Committee; House Science, Space, and Technology Committee, Subcommittee on Natural Resources, Agriculture Research, and Environment; and Technology Assessment Board Members Evans, Hatch, Kennedy, Pell, and Udall.

U.S. FOREIGN POLICY INTERESTS IN AFRICA

Humanitarian interests clearly top the list of why the general public believes that the United States should provide assistance to developing countries and 39 percent recognize Africa as a region deserving priority attention (6).[2] An unprecedented outpouring of U.S. governmental and private resources followed the 1984-85 television broadcasts showing starving Africans, and these contributions surely saved many lives. As the head of the United Nations Office of Emergency Operations in Africa, Maurice Strong, said of the recent famine: "Certainly, thousands and thousands did die, and hundreds of thousands suffered. But the big news is that 35 million people who might have died, didn't" (2).

However, the support stimulated by crises fades quickly with improving situations, such as the return of rainfall to drought-stricken regions in Africa. Yet people familiar with the situation know the return of rain is only a temporary respite in a deteriorating situation. Severe famine already threatens Ethiopia again in 1988, where political and economic policies have exacerbated serious drought-induced food shortages.

Humanitarian support will continue to be essential during periods of crisis, but it will do little to provide long-term solutions to Africa's food security problems. Many African farmers, herders, and fishers are now caught in a cycle of poverty, malnutrition, and environmental degradation that increasingly undermines their future. Humanitarian assistance can be effective in responding to the symptoms of this condition, but breaking the cycle requires promoting sustainable economic development. For most Africans, enhanced agriculture offers the most realistic opportunity to achieve this.

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[2] Africa received about 9 percent of U.S. bilateral foreign aid allocated for fiscal year 1987 (18).

A "bare majority" of Americans supports U.S. *economic aid* to developing countries (8), a level that has remained steady for almost four decades (6). Such aid is commonly aimed at addressing some of the fundamental economic and social problems affecting poor countries, for example, by supporting agricultural development, family planning, and preventative health care. Many people find that U.S. and African economic interests both can be served by promoting African economic development, particularly through its agricultural sector.

This mutual interest stems from the realization that expanded U.S. trade opportunities depend directly on improved prosperity and purchasing power in developing countries. Conversely, poor economic performance in the developing world has serious repercussions for the U.S. economy. Developing countries bought 40 percent of U.S. exports and represented the fastest growing markets for U.S. goods by the end of the 1970s. Developing countries are likely to remain important U.S. markets because 90 percent of the projected population increase of 2 billion people by 2010 is expected to be there. Mounting debt and falling commodity prices have slowed the growth of developing country imports of U.S. goods since the late 1970s. The impact of the 1980s recession on developing countries is credited with causing one-half the decline of U.S. exports between 1980 and 1985, as well as a corresponding loss of some 1.7 million U.S. jobs (26). Declines in U.S. agricultural exports alone between 1980 and 1986 resulted in the loss of an estimated 500,000 U.S. jobs in farming and related input and service sectors (29).

Whether Africa offers a growing field of trade and economic cooperation for the United States will depend on the future growth of African economies. The continent is not now a major market for U.S. products, nor will it likely become one in the near future (27). Therefore, U.S. economic interests in promoting food security and economic development in the region can only be viewed as a long-term investment—so that in the future healthier economies, improved infrastructures, and larger markets, may lead Africa to a more prominent place in U.S. economic relations.

U.S. economic interests, however, seldom assume such a long-term view. And short-term economic goals can conflict with efforts to enhance low-resource agriculture. For example, African urban markets receive approximately $1 billion of U.S. agricultural exports a year, mainly grain (22). American policy to expand grain exports and African policies subsidizing imported grains both act to keep urban food prices low and can reduce or destabilize prices for locally produced food (28), an important source of income for low-resource farmers and herders. It is politically difficult, however, to promote policies to curtail certain U.S. exports and African subsidies as a way to stimulate local agriculture—even in cases where this may be in the longer-term interests of African and U.S. economies alike (35).

The United States also pursues foreign policy objectives in Africa based on a number of *political and security interests* (14, 34):

- Africa, with its bloc of 46 nations, can play a decisive role in international organizations and meetings.
- The United States relies on Africa for important natural resources, now importing more oil from Sub-Saharan Africa than from the Middle East or North Africa (22). The United States also imports at least 90 percent of its cobalt, bauxite, and manganese, with 25-50 percent coming from African countries (10, 32, 33).
- The continent is strategically located, with deep-water ports, good airfields, and controlling positions in relation to major waterways and air corridors.
- Continuing regional conflicts make Sub-Saharan Africa a potential arena for confrontation between external powers and economic stagnation could lead to greater internal instability.

- The U.S. supports democratic institutions and civil rights in Africa. Particular attention is directed to dismantling apartheid in South Africa, for example.

U.S. political and strategic interests usually are pursued via diplomatic channels and shift from Administration to Administration. Congressional and Administration attention to these issues tends to be sporadic and center on single issues or regions with high visibility (15, 30). Volatility is also a function of political instability in many African countries (37). With this, political winds can shift quickly in U.S. relations with African countries, and it is not unusual for long-term development interests to be swept up in the process.

Agricultural assistance programs can be affected markedly when Congress or the Administration cuts or restricts funds or closes AID missions for political reasons. Years of investment in agricultural research and development can be lost because of these disruptions. Poor farmers and herders are particularly vulnerable to these changes because they have few resources to re-invest elsewhere if they lose what they had invested in discontinued projects. Also, such experiences may undermine their willingness to participate in future development efforts.

Some U.S. programs, however, are less susceptible than others to the impacts of political pressures. For example, Congress stipulated that the African Development Foundation be independent of short-term U.S. political interests. This approach seems particularly important for enhancing low-resource agriculture because such support must be long-term and dependable to be effective.

Thus, while it is true that the United States has humanitarian, economic, and political interests in aiding Africa's poor farmers and herders, these interests often have conflicting dimensions that alternately support and counteract U.S. attempts to provide effective development assistance.

THE EFFECTS OF SUPPORT FOR AFRICAN FARMERS ON U.S. AGRICULTURE

U.S. farm trade suffered an overall decline during the 1980s, with some commodities losing market shares to *foreign competition*. Some U.S. farm groups have voiced concern that several developing countries are increasingly competitive in world markets and note that U.S. agricultural assistance has helped these countries improve efficiency (38). Legislators from farm states have used legislation to curtail U.S. support for certain crops in developing countries when the United States exports the same ones.

On the other hand, U.S. farm interest groups generally recognize the importance of assisting developing countries achieve the broad-based per capita income growth necessary to create demand and foreign exchange for buying U.S. agricultural exports. For many developing countries, such economic growth requires agricultural development and, thus, technological assistance to increase production and incomes.

Recent analyses suggest that, in the long-term, stimulating African development will have greater benefits for U.S. agriculture generally than attempts to limit U.S. technical assistance to African farmers. A strong correlation exists between increased farm production in developing countries and increased agricultural imports (20). For example, annual net staple food imports increased in volume by 133 percent between 1961-65 and 1974-76 for 16 agriculturally successful developing countries—those with the most rapid growth rates in staple food production (3). Similar results occurred in a study of agricultural economies in Malaysia and Brazil, usually cited as two of the most threatening competitors to U.S. global markets (16).

Despite rapid agricultural development in both countries during the period 1967 to 1983, Malaysia at least doubled imports of food, feed grains, and oilseeds, and Brazil increased both farm exports and imports, particularly of grains. Generally, the dollar value of per capita agricultural imports in agriculturally successful developing countries grew 47 percent between 1970 and 1980, while it grew only 37 percent among agriculturally unsuccessful countries.

> The conclusion to which all this evidence points is that for developing countries, increases in agricultural production are necessary for widespread income growth, which leads to increases in agricultural imports. Because of this, developing countries with the faster-growing agricultural sectors were the faster-growing markets for U.S. agricultural exports. Thus, American agriculture has nothing to gain and much to lose from slowing down agricultural development in developing counties (12).

Cases exist were the positive link between agricultural development and agricultural imports in developing countries has been severed. Macroeconomic factors (e.g., world commodity or energy prices) and national policies (e.g., those that distort free-market mechanisms) are considered the major causes (20, 38). These exceptions do not negate the strong potential for encouraging mutually beneficial partnerships between U.S. exporters and developing countries but they do suggest the need for close, case-by-case analysis. Such analysis, however, may be hampered because the United States monitors and evaluates other countries' agricultural policies inadequately (24).

Other problems can arise because net benefits to American agriculture does not mean only that all farmers and ranchers will benefit or benefit equally. For example, Brazil is a growing market for U.S. grain but it also is a growing soybean exporter, which U.S. soybean growers note with alarm. The benefits of expanding trade tend to be spread over a large segment of the population (e.g., to U.S. consumers), whereas the costs tend to be more concentrated (e.g., among the producers of a given commodity). The latter groups are more likely to rally support and lobby for favorable policies, tipping public debate in one direction.

U.S. commodity groups have effectively restricted U.S. foreign assistance from supporting commodities that compete with U.S. exports. Restrictions on bilateral assistance appear in the Bumpers Amendment to the FY 1987 Foreign Operations Appropriations Bill and a similar statement in the Continuing Resolution for 1988 (HR 3750) restricts U.S. support for multilateral development banks. The Bumpers Amendment states that no funds shall be expended under the Foreign Assistance Act for:

> . . . any testing or breeding feasibility study, variety improvement or introduction, consultancy, publication, or conference training in connection with the growth of production in a foreign country of an agricultural commodity for export which would compete with a similar commodity grown or produced in the United States.

Such restrictions protect particular interests but their broader effects can be problematic. Sometimes U.S. interests in increasing exports may require supporting commodities grown overseas that are also grown by the United States. Also, the United States generates significant ill-will by trying to block all World Bank loans to developing countries to grow certain crops that will compete with U.S. agriculture (17).

Also, broad-brush bans do not adequately address how American policy should vary based on different countries' development needs and competitive position. This issue has particular relevance for Sub-Saharan Africa where development needs are great and where countries are unlikely to threaten U.S. exports. African export capacity is not a significant threat to U.S. producers and the types of crops grown are not, for the most part, major U.S. export commodities. Some provisions exist in current legislation to address such circumstances. For example, the Bumpers Amendment contains provisions to allow research and other support for competing crops if the production is deemed necessary for the internal food security of the developing country in question (38). However, indications exist that once broad research restrictions are in place for a given commodity, a *de facto* research ban may result for countries where increased production presents little or no threat to U.S. exporters.

Africa cannot be isolated from the adverse impacts of existing restrictions on global support for U.S. agricultural assistance. Of particular concern are prospects that restrictive legislation could have negative effects on the international research networks that have an important role to play in improving African agricultural development. In particular, concerns exist regarding the consequences for the various International Agricultural Research Centers (IARCs).

The IARCs are institutions created specifically to develop new information and technology on the world's major food commodities, with specific attention to developing country needs. A number of these commodities are also major U.S. exports, for example, maize and wheat. Since the United States contributes 20 to 25 percent of the IARC's core budget, a major reduction in contributions could deal a severe blow to their capacity to generate, adapt, and transfer technology to developing countries and bolster national research in Sub-Saharan Africa and elsewhere (38). Reductions could also undermine the important role these institutions play in international agricultural research and in conserving and distributing germplasm. Many future improvements in agriculture are likely to be based on the IARCs' work—including improvements in U.S. agriculture.

Much debate regarding the U.S. role in agricultural assistance has focused on international competition for export markets. U.S. agriculture has additional, non-competitive relationships with the rest of the world, however, and the U.S. farm sector receives *direct and indirect benefits from U.S. development assistance*. Approximately 70 percent of funds for direct bilateral assistance are actually spent in the United States (36). The figure for agricultural aid may be as high as 90 percent (38). Expenditures for technical assistance, commodities, and training are paid to U.S. citizens, companies, and schools. These figures belie the perception that agricultural assistance only benefits its recipients. They also raise questions whether this high proportion of budget expenditures used for U.S. products and services is the most efficient and sustainable means of supporting African development.

American farmers also derive direct benefits from government purchases of U.S. agricultural commodities for food aid, as established under the Agricultural Trade Development and Assistance Act of 1984 (Public Law 480). Since their inception, Public Law 480 programs have purchased U.S. farm products from virtually every state at a total of at least $35 billion (31).

Indirect benefits are more difficult to quantify but clearly are substantial. They include "reverse technology transfer" from developing countries generally and Africa in particular, often gained through U.S. involvement in international research. These benefits come in many forms, from specific technology, to research insights, to genetic material collected while working with traditional varieties of crops overseas. Examples include:

- Barley is worth $140 million per year to California farmers. Current varieties' resistance to yellow dwarf virus, a potentially devastating disease, is due to a single barley gene from Ethiopia (23).
- Genetic resistance to wheat rust, another major crop disease, comes from Kenya (5).
- A sizable portion of Nebraskan sorghum was derived from parental varieties introduced from Nigeria in 1951 (7).
- In 1986, USDA released new pearl millet germplasm that is resistant to two major U.S. diseases based on a wild subspecies discovered in Senegal (1).
- U.S. ranchers from Texas to the Carolinas may benefit from a new breed of cattle that has greater tolerance to hot and dry weather, like its West African and English parent stock (11).

Genetic resources provide benefits to American agriculture beyond their use as breeding material for improved yield or resistance. Leaf miners, an agricultural pest, cause at least $15 million damage to California's crops. A newly-approved pesticide controlled up to 95 percent of these pests in USDA tests. Its active ingredient originates in tropical African and Asian neem trees where it has been a traditional means of fighting insects for centuries (4).

Other indirect benefits to U.S. agriculture come from supporting agricultural research in Africa. U.S. researchers, stimulated by experiences with different kinds of agriculture overseas, exchange knowledge and research approaches. The new ideas coming from returning university scientists, Peace Corps Volunteers, and from foreign visitors to the United States clearly are important:

> We need to forget the idea (rhetoric) that we are the technological leader in every area and that our perspective should be to share our technology rather than to obtain it from others. To preserve our own competitive position it is imperative that we tap into the new knowledge being generated elsewhere (24).

Farming systems research originated overseas, with much of the early work occurring in East Africa. Now, because of growing concern for small farms in the United States increased effort is being directed to applying farming systems approaches here: Colorado State University has farming systems work underway in western Colorado, and researchers at Morehead State University see applications in eastern Kentucky. Much of the universities' expertise was first gained in Africa. Interest in reduced pesticide use has attracted growing attention to integrated pest management. Farmers in developing countries, including in Africa, have developed many agronomic practices to reduce pest problems without pesticides. These practices may offer important information for devising U.S. approaches (21).

CONCLUSION

The main goal of U.S. development assistance, although it is sometimes forgotten by expatriates but seldom by Africans, is to work itself out of job. The Agency for International Development lists 15 countries, in 4 regions of the world, as "graduates" from development assistance (8). So the U.S. record is not without its successes. Considerable frustration has emerged, however, due to the general ineffectiveness of development assistance. The disappointing record in Africa, despite considerable infusion of funds, is a major source of this frustration.

It is almost inevitable that people looking at development assistance in Africa will try to make comparisons to the successes of the U.S. Marshall Plan to support rebuilding war-torn Europe and assistance to Asia in the 1950s. But such comparisons are misleading. Institutional and other constraints—not to mention a diverse and challenging environment—make development assistance to Africa fundamentally more difficult than was the case elsewhere.

It is also important to remember that U.S. foreign assistance reached as high as 3 percent of the U.S. gross national product (GNP) in the late 1940s (25). It has fallen to about one-tenth that level today, and it is one-half of what it was only 20 years ago. The United States now ranks near the bottom of industrialized countries in terms of percent of GNP devoted to development assistance, although the total dollar amount of U.S. aid is the highest (26). Some experts fear that U.S. foreign aid budgets are now too low to meet U.S. interests in Africa's development, as well as broader U.S. interests and responsibilities overseas (19).

Much of the American public, however, perceives that the United States spends too much on foreign assistance (6). Some Americans believe that as much as 40 percent of the U.S. budget goes to development aid. In fact, this figure is 1 percent or less (8), and farmers in Iowa alone received more federal loans and aid in 1987 than the World Bank provided for all of Africa (13).

Whether the U.S. invests too much or too little in meeting its interests in Africa is a subject that will continue to be debated. Expectations that dramatic short-term results are possible are misguided, though, even if increased funding was available. Further, when frustration over the slow pace of progress leads to frequent shifts in U.S. development priorities, long-term impact is undermined. Stability of funding, then, can be as important as funding levels. The creation of the African Development Fund as well as Congress' continued emphasis on agricultural assistance are promising steps in what can be a resource-enhancing approach for U.S. development assistance.

Nevertheless, the road to African food security seems long and difficult. Decisions on how to address the challenges are African ones. But the United States has stated, in its foreign assistance legislation, a desire to be a partner in this work. And an approach that enhances low-resource agriculture will be an important component of any effective U.S. development assistance effort.

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Appendixes

Appendix A
The Assessment's Contractor Reports

Part A: Principles of Low-Resource Agriculture

Report: "Low-Resource Agriculture in Sub-Saharan Africa: Principles and Concepts for Managing Natural Resources"

Coauthors: C. Gregory Knight, Department of Geography, Pennsylvania State University, University Park, PA and R. Dennis Child, Winrock International, Morrilton, AR

Reviewers:[2]
- Miguel Altieri, Division of Biological Control, University of California, Berkeley, CA
- John H. Grover, Department of Fisheries and Allied Aquacultures, Auburn University, Auburn, AL
- James Newman, Department of Geography, Syracuse University, Syracuse, NY
- Roald A. Peterson, Fayetteville, AR
- M.J. Trlica, Department of Range Science, Colorado State University, Ft. Collins, CO
- Gene C. Wilken, Department of Economics, Colorado State University, Ft. Collins, CO

Report: "Low-Resource Agriculture in Sub-Saharan Africa: Principles and Concepts for Managing Inland Fisheries"

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- Frank Meriwether, Agricultural Research Center, University of Arkansas at Pine Bluff, Pine Bluff, AR
- Richard A. Neal, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC
- Roger Palm, South Carolina Aquaculture/ Mariculture Programs International, University of South Carolina, Columbia, SC
- Richard B. Pollnac, International Center for Marine Resource Development, University of Rhode Island, Kingston, RI
- Harry Rea, Office of Training and Program Support, U.S. Peace Corps, Washington, DC
- Ted Scudder, Cape Tribulation, Queensland, Australia

Report: "Principles and Concepts of Productive Human Resource Systems"

Author: Anne Fleuret, Department of Anthropology, American University, Washington, DC

Reviewers:
- Ronald Cohan, University of Florida, Gainesville, FL
- Kathleen Staudt, Office of the Dean of Liberal Arts, University of Texas, El Paso, TX

Report: "Principles and Concepts of Effective Institutions"

Author: Milton Esman, Department of Government, Cornell University, Ithaca, NY

Reviewers:
- David Atwood, Science and Technology Bureau, U.S. Agency for International Development, Washington, DC
- Michael Bratton, Office of the Representative for Eastern and Southern Africa, The Ford Foundation, Nairobi, Kenya
- James Harbeson, International Studies Program, City University of New York, New York, NY
- Dennis Rondinelli, Syracuse, NY

Report: "Integrating Principles and Concepts for Managing Natural, Human, and Institutional Resources" (not available from NTIS)

Author: Raymond Noronha, Washington, DC

Report: "Incorporating Participatory Approaches in Institutions"

Authors: Paula Donnelly-Roark and Grace Hemmings-Gaphihan, Donnelly-Roark & Associates, Washington, DC

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[1] These contractor reports should be requested as Volume 2 (Contract Papers) of this assessment from the National Technical Information Service, Springfield, VA 22161, telephone (703) 487-4650. NTIS accession numbers for paper or microfiche copies are:
- Part A: Principles of Low-Resource Agriculture, PB 88 201 280 /AS.
- Part B: The USDA Data Base and the Potential of Low-Resource Agriculture, PB 88 201 298 /AS.
- Part C-1: Development Assistance and Low-Resource Agriculture, PB 88 201 306 /AS.
- Part C-2: Development Assistance and Low-Resource Agriculture, cont, PB 88 201 314 /AS.
- Part D: Technology Papers, PB 88 201 322 /AS.

[2] Advisory Panelists also reviewed each of these Contractor Reports.

Reviewers:
Earl M. Brown, African Development Foundation, Washington, DC
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Report: "Low-Resource Agriculture and African Institutional Development"
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Part B: The USDA Data Base and the Potential of Low-Resource Agriculture

Report: "The Potential of Low-Resource Agriculture in African Development"
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Report: Potentials for Development in Low-Resource Technologies for African Agriculture"
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Donald Plucknett, Consultative Group on International Agricultural Research, Washington, DC
Kenneth Swanberg, Office of International Cooperation and Development, U.S. Department of Agriculture, Washington, DC

Report: "The Role of Low-Resource Agriculture in Africa:"
"Overview and Summary"
"Kenya Supplementary Information"
"Malawi Supplementary Information"
"Mali Supplementary Information"
"Nigeria Supplementary Information"
"Senegal Supplementary Information"
"Sudan Supplementary Information"
"Zaire Supplementary Information"
"Zimbabwe Supplementary Information"
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Part C-1. Development Assistance and Low-Resource Agriculture

Report: "African Perspectives on Low-Resource Agriculture"
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Richard Ford, International Development Program, Clark University, Worcester, MA
Thomas M. Painter, Social Science Research Council, New York, NY
Bill Rau, Bread for the World, Washington, DC

Report: "African Models of Developmental Assistance to Low-Resource Agriculture"
Author: Robert J. Cummings, African Studies and Research Program, Howard University, Washington, DC
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Bill Rau, Bread for the World, Washington, DC
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ican Studies, University of Maryland Baltimore County, Baltimore, MD

Report: "Existing Models of Development Assistance to Low-Resource Agriculture in Africa"
Author: Carol Lancaster, School of Foreign Service, Georgetown University, Washington, DC
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Stephen Commins, African Studies Center, University of California, Los Angeles, CA
Charles Hanrahan, Abt Associates, Inc., Washington, DC
William Haven North, Bureau for Policy Planning and Coordination, U.S. Agency for International Development, Washington, DC

Report: "Alternative Models of Development Assistance to Low-Resource Agriculture in Africa"
Author: Celia Jean Weidemann, Washington, DC
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Report: "U.S. Domestic Policy Dilemmas Affecting Development Assistance"
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Robert L. Paarlberg, Center for International Affairs, Harvard University, Cambridge, MA
John L. Woods, International Program for Agricultural Knowledge Systems, University of Illinois, Urbana, IL

Report: "Case Studies: Factors Influencing Agricultural Production of Small Farmers in Zimbabwe and Malawi
Author: Kathleen Desmond, Arlington, VA
Reviewers:
Kathleen Cloud, Women in Development Office, University of Illinois, Urbana, IL.
George Honade, Development Alternatives, Inc., Washington, DC
John Staatz, Department of Agricultural Economics, Michigan State University, East Lansing, MI

Report: "Government Assisted Land Settlement: Status and Potential in African Low-Resource Agriculture"
Author: Della E. McMillan, Department of Anthropology, University of Kentucky, Lexington, KY
Reviewers:
Pat Fleuret, Bureau for Africa, U.S. Agency for International Development, Washington, DC
Ted Scudder, Cape Tribulation, Queensland, Australia

Part C-2: Development Assistance and Low-Resource Agriculture (continued)

Report: "Links Between the Private Enterprise and Low-Resource Agriculture in Sub-Saharan Africa"
Author: Arthur Gibb, Jr., Department of Economics, U.S. Naval Academy, Annapolis, MD
Reviewers:
Michael Farbman and Frank Denton, Bureau for Africa, U.S. Agency for International Development, Washington, DC
Joel Greer, National Security and International Affairs Division, General Accounting Office, Washington, DC
Steve Haggblade, Metropolitan Studies Program, Syracuse University, Syracuse, NY
Frances Brigham Johnson, U.S. Agency for International Development, Washington, DC

Report: "Strategies for Development of the Private Sector and Its Links with Low-Resource Agriculture"
Coauthors: Galen Hull and Guy Gran, Kensington, MD
Reviewers:
Michael Farbman and Frank Denton, Bureau for Africa, U.S. Agency for International Development, Washington, DC
Steve Haggblade, Metropolitan Studies Program, Syracuse University, Syracuse, NY
Frances Brigham Johnson, U.S. Agency for International Development, Washington, DC

Report: "New Models for Low-Resource Agricultural Research and Extension in Sub-Saharan Africa"
Author: Paul Richards, Anthropology Department,

University College London, London, United Kingdom

Reviewers:

- Robert Chambers, Institute of Development Studies, University of Sussex, Brighton, UK
- Jane I. Guyer, Mary Ingraham Bunting Institute, Radcliffe College, Cambridge, MA
- Janice Jiggins, Andelst, Netherlands
- Robert M. Netting, Department of Anthropology, University of Arizona, Tucson, AZ

Report: "Farming Systems Research and Extension: Status and Potential in Low-Resource Agriculture"

Coauthors: Susan V. Poats, Daniel Galt, Chris Andrew, Lisette Walecka, Peter Hildebrand, and Kenneth McDermott, Farming Systems Support Project, University of Florida, Gainesville, FL

Reviewers:

- Billie R. DeWalt, Department of Anthropology, University of Kentucky, Lexington, KY
- Tim Frankenberger, Office of Arid Lands Studies, University of Arizona, Tucson, AZ
- Bruce F. Johnston, Food Research Institute, Stanford University, Stanford, CA
- Kenneth Swanberg, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC
- Hubert G. Zandstra, Agriculture, Food, and Nutrition Sciences, International Development Research Center, Ottawa, Canada

Part D: Technology Papers

Report: "Soil Fertility Maintenance in Sub-Saharan Africa"

Coauthors: Paul L.G. Vlek, A.U. Mokwunye, and M.S. Mudahar, International Fertilizer Development Center, Muscle Shoals, AL

Reviewers:

- William R. Greenwood, Office of International Geology, U.S. Geological Survey, Reston, VA
- Raymond E. Meyer, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC
- Arthur B. Onken, Texas Agricultural Experiment Station, Lubbock, TX
- John H. Sanders, Department of Agricultural Economics, Purdue University, West Lafayette, IN
- Charles Steedman, Center for Research on Economic Development, University of Michigan, Ann Arbor, MI

Report: "Crop Rotation and Residue Management"

Author: Rattan Lal, International Institute for Tropical Agriculture, Ibadan, Nigeria

Reviewers:

- Frank G. Calhoun, International Programs in Agriculture, Columbus, OH
- George C. Taylor, North Carolina State University, Raleigh, NC
- Charles W. Wendt, Texas Agricultural Experiment Station, Texas A&M University, Lubbock, TX
- Wayne O. Willis, Colorado State University, Ft. Collins, CO

Report: "Five Small-Scale Water Management Technologies"

Author: W. Gerald Matlock, Desert Agricultural and Technology Systems, Inc., Tucson, AZ

Reviewers:

- E. Walter Coward, Department of Rural Sociology, Cornell University, Ithaca, NY
- Raymond E. Meyer, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC
- B.A. Stewart, Southern Plains Area Conservation and Production Research Laboratory, U.S. Department of Agriculture, Bushland, TX
- Lyman S. Willardson, Department of Agricultural and Irrigation Engineering, Utah State University, Logan, UT

Report: "Soil and Water Management in the Humid and Highland Zones of Africa"

Author: Laurence A. Lewis, Graduate School of Geography, Clark University, Worcester, MA

Reviewers:

- Daniel C. Clay, International Statistical Programs Center, Bureau of the Census, Washington, DC
- Raymond E. Meyer, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC
- Philip W. Porter, Department of Geography, University of Minnesota, Minneapolis, MN
- Bob J. Walter, Department of Geography, Ohio University, Athens, OH

Report: "Low-Resource, Small-Scale Irrigation in Africa"

Author: Alfred S. Waldstein, Associates in Rural Development, Burlington, VT

Reviewers:

- Guy LeMoigne, Agriculture and Rural Development Department, World Bank, Washington, DC

Report: "Intercropping in Low-Resource Agriculture in Africa"

Author: David J. Andrews, Department of Agronomy, University of Nebraska Lincoln, NE

Reviewers:
- Dana Dalrymple, Consultative Group on International Agricultural Research, U.S. Agency for International Development, Washington, DC
- Raymond E. Meyer, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC
- John H. Sanders, Department of Agricultural Economics, Purdue University, West Lafayette, IN

Report: "Challenges of Intercropping: Policy Issues"

Author: Charles A. Francis, Department of Agronomy, University of Nebraska, Lincoln, NE

Reviewers:
- Dana Dalrymple, Consultative Group on International Agricultural Research, U.S. Agency for International Development, Washington, DC
- Raymond E. Meyer, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC
- John H. Sanders, Department of Agricultural Economics, Purdue University, West Lafayette, IN

Report: "Agroforestry in Africa"

Author: Roy T. Hagen, Esko, MN

Reviewers:
- Steven R. Brechin, School of Natural Resources, University of Michigan, Ann Arbor, MI
- Bruce B. Burwell, Natural Resources Sector, U.S. Peace Corps, Washington, DC
- Dennis Johnson, Forestry Support Program, U.S. Forest Service, Washington, DC
- Michael McGahuey, Chemonics, Inc., Washington, DC
- Fred R. Weber, Boise, ID

Report: "Crop Breeding for Low-Resource Agriculture: Overview, Rice, Food Legumes"

Author: Ivan W. Buddenhagen, Department of Agronomy, University of California, Davis, CA

Reviewers:
- David J. Andrews, Department of Agronomy, University of Nebraska, Lincoln, NE
- Charles A. Francis, Department of Agronomy, University of Nebraska, Lincoln, NE
- Donald Plucknett, Consultative Group on International Agricultural Research, Washington, DC
- Johannes ter Vrugt, The World Bank, Washington, DC

Report: "Millet Breeding for Low-Resource Agriculture in Africa"

Authors: David J. Andrews, Department of Agronomy, University of Nebraska, Lincoln, NE

Reviewers:
- Glenn W. Burton, Coastal Plain Experiment Station, Tifton, GA
- Wayne W. Hanna, Coastal Plain Experiment Station, Tifton, GA

Report: "Maize Breeding"

Author: Sherman F. Pasley, Office of International Programs, University of Florida, Gainesville, FL

Reviewers:
- L.L. Darrah, North Central Region Crop Production Research Unit, U.S. Department of Agriculture, Columbia, MO
- Paul Gibson, Plant and Soil Science, Southern Illinois University, Carbondale, IL

Report: "Sorghum Breeding"

Authors: Fred R. Miller and John A. Mann, Department of Soil and Crop Science, Texas A&M University, College Station, TX

Reviewers:
- David J. Andrews, Department of Agronomy, University of Nebraska, Lincoln, NE
- John Axtell, Department of Agronomy, Purdue University, West LaFayette, IN

Report: "Root Crop Breeding"

Author: Walter A. Hill and Conrad Bonsi, Office of International Programs, Tuskegee University, Tuskegee, AL

Reviewers:
- John C. Bouwkamp, Department of Horticulture, University of MD, College Park, MD
- Afred Jones, U.S. Vegetable Laboratory, U.S. Department of Agriculture, Charleston, SC
- Jill E. Wilson, Research Coordinator, University of the South Pacific, Apia, Western Samoa

Report: "Pest Control"

Author: Dale G. Bottrell, Department of Entomology, University of Maryland, College Park, MD

Reviewers:
- Andrea Blumberg, U.S. Agency for International Development, Washington, DC
- Carroll W. Collier, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC

Raymond E. Frisbie, Department of Entomology, Texas A&M University, College Station, TX
Agi Kiss, Office of Environmental and Scientific Affairs, The World Bank, Washington, DC

Report: "Postharvest Technology"
Author: Tropical Development and Research Institute, London, UK

Reviewers:
Thomas V. Dechert, Postharvest Institute for Perishables, University of Idaho, Moscow, ID
Kenton Harris and Carl Lindblad, Volunteers in Technical Assistance, Arlington, VA
John R. Pederson, Food and Feed Grains Institute, Kansas State University, Manhattan, KS

Report: "Communication and Information Technologies"
Author: Frances B. Hays, Academy for Educational Development, Washington, DC

Reviewers:
Gary L. Garriott, Volunteers in Technical Assistance, Arlington, VA
John K. Mayo, Centre for the Study of Communication and Culture, London, UK
Anthony J. Meyer, Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC
Joseph N. Pelton, Intelsat, Washington, DC
Ewart Skinner, Department of Communication, Purdue University, West Lafayette, IN

Appendix B

Participants in Assessment Workshops

OTA held five workshops during this assessment. Participants are listed here.

African Arid/Semiarid Lands Technology Working Group Apr. 28, 1986

Steve Franzel
Development Alternatives, Inc.
Washington, DC

Dolores Koenig
American University
Hurst Hall
Washington, DC

Peter Little
Institute for Development Anthropology
Binghampton, NY

Mike McGahuey
Chemonics, Inc.
Washington, DC

Ray Meyer
Bureau for Science and Technology
Agency for International Development
Washington, DC

Gregory Booth
U.S. Bureau of Land Management
Washington, D.C.

Workshop on the Structure and Function of Congress May 22, 1986

Congressional Research Service

Susan Abbasi
Environment and Natural Resources Division

Barry Carr
Environment and Natural Resources Division

Susan Epstein
Environment and Natural Resources Division

Larry Nowels
Foreign Affairs and National Defense Division

Paul Rundquist
Government Division

Workshop on Technology for Low-Resource Agriculturalists in Arid and Semiarid Sub-Saharan Africa May 29-30, 1986

Chair: Tim Frankenberger
Office of Arid Land Studies
University of Arizona
Tucson, AZ

Haidari Amani
Department of Economics
University of Dar-es-Salaam
Dar-es-Salaam, Tanzania

David Andrews
Department of Agronomy
University of Nebraska
Lincoln, NE

Carl Bielenberg
Appropriate Technology International
Washington, DC

Trent Bunderson
International Program Development Office
Washington State University
Pullman, WA

Helen Henderson
Bureau of Applied Research and Anthropology
University of Arizona
Tucson, AZ

Michael Horowitz
Director
Institute for Development Anthropology
State University of New York
Binghamton, NY

Melanie Marlett
Arlington, VA

Michael McGahuey
Chemonics, Inc.
Washington, DC

Ray Meyer
Bureau for Science and Technology
Agency for International Development
Washington, DC

William Phelan
International Agriculture Program
Cornell University
Ithaca, NY

Tim Resch
Forestry Support Program
U.S. Forest Service
Washington, DC

Michael Roth
Department of Agricultural Economics
Purdue University
West Lafayette, IN

Allan Savory
Center for Holistic Resource Management
Albuquerque, NM

Ian Stewart
World Hunger Alleviation through Response Farming
Davis, CA

Walter Zisette
Mercer Island, WA

Workshop on Integration of Principles and Concepts for Management of Natural, Human, and Institutional Resources in Sub-Saharan Africa

June 12-13, 1986

Chair: Leonard Berry
Provost's Office
Clark University
Worcester, MA

Dennis Child
Winrock International
Morrilton, AR

Milton Esman
Department of Government
Cornell University
Ithaca, NY

Anne Fleuret
Department of Anthropology
American University
Washington, DC

Louise Fortmann
Department of Forestry
University of California
Berkeley, CA

Peter Hildebrand
Food and Resource Economics Department
University of Florida
Gainesville, FL

Gregory Knight
Department of Geography
The Pennsylvania State University
University Park, PA

Raymond Noronha
Alexandria, VA

Workshop on Development Assistance

Aug. 26-27, 1986

Chair: Mary B. Anderson
Consultant in International
Economic Development
Harvard University
Cambridge, MA

Robert Cummings
African Studies and Research Program
Howard University
Washington, DC

Milton Esman
Department of Government
Cornell University
Ithaca, NY

George Honadle
Development Alternatives, Inc.
Washington, DC

Nadine Horenstein
International Center for Research on Women
Washington, DC

Carol Lancaster
Director of African Studies
School of Foreign Service
Georgetown University
Washington, DC

C. Jean Weidemann
Arlington, VA

Karen Weise
Associates in Rural Development
Burlington, VT

Appendix C
African Correspondents

The following African scientists and policymakers provided analyses of food security and low-resource agriculture in their regions. They responded to OTA's request for letters or publications regarding 1) whether an agrarian crisis existed, 2) whether OTA's model of "low-resource agriculture" was accurate and appropriate, 3) how their views differed from others, and 4) how U.S. foreign assistance could be improved.

Dr. Adetokunbo O. Adeola
Forestry Research Institute of Nigeria
Ibadan, Nigeria

Dr. Emmanuel N. Agwuna
Federal Livestock Department
Federal Secretariat
Lagos, Nigeria

Mr. O. Awoyemi
Federal Department of Agriculture and Rural Development
Federal Ministry of Agriculture, Water Resources, and Rural Development
Federal Secretariat
Lagos, Nigeria

Dr. Bifuko Baharanyi
Fulbright Scholar-in-Residence
Department of Political Science
Johnson C. Smith University
Charlotte, NC

Dr. Solomon Bekure
Team Leader
International Livestock Centre for Africa
Kenya Country Program
Nairobi, Kenya

Professor J. Malcolm Blackie
Faculty of Agriculture
Department of Agricultural Economics
University of Zimbabwe
Salisbury, Zimbabwe

Mr. G.H.R. Chipande
Chancellor College
University of Malawi
Zomba, Malawi

Mr. Ousmane Nafolo Coulibaly
Department of Agricultural Economics
Michigan State University
East Lansing, MI

Dr. Bahiru Duguma
International Livestock Centre for Africa
Small Ruminant Programme
Ibadan, Nigeria

Dr. A. Mamdouh El-Baz
Director
Centre on Integrated Rural Development for Africa
Arusha, Tanzania

Dr. José Adriano M. Fernandes
Deputy National Director of Agrarian Economy
c/o Ministry of Agriculture
Maputo, People's Republic of Mozambique

Mr. Robinson L. Gapare
President
The National Farmers Association of Zimbabwe
Harare, Zimbabwe

Dr. Leland R. House
Executive Director
SADCC/ICRISAT Sorghum-Millet Improvement Program
Balawayo, Zimbabwe

Dr. Mengistu Hulluka
Department of Plant Pathology and Microbiology
Texas A&M University
College Station, TX

Mr. S. N. Kassapu
Regional Science and Technology Officer
U.N. Food and Agriculture Organization
Regional Office for Africa
Accra, Ghana

Dr. C.L. Keswani
Technical Advisor
Ministry of Lands, Agriculture and Rural Resettlement
Department of Research and Specialist Services
Plant Protection Research Institute
Harare, Zimbabwe

Dr. Fassil G. Kiros
Addis Ababa
Ethiopia

Dr. Aziadome Kogblevi
Directeur du Centre National
d'Agro-Pedologie
Cotonou, Republique Populaire Du Benin

Dr. Jumanne Abdallah Maghembe
Associate Professor
Department of Forest Science
Oregon State University
Corvallis, OR

Dr. M. S. Matsebula
Associate Professor
Department of Economics
University of Delaware
Newark, DE

Dr. Assefa Mehretu
Associate Professor
Department of Geography
Michigan State University
East Lansing, MI

Dr. Abukar M. Mohamed
Crop Science Research Laboratory
Corn Host Plant Resistance Research Unit
Mississippi State, MS

Ms. Ntombana R. Mugabe
Deputy Director
Department of Research and Specialist Services
Ministry of Agriculture
Harare, Zimbabwe

Dr. Massa Mukambo
Chargé d'Etudes
Service Présidentiel d'Etudes (S.P.E.)
Agriculture et Développement Rural
Bureau du Président de la République
Kinshasa, Zaire

Dr. Rukudzo Murapa
Head
Department of Political and Administrative
 Studies
University of Zimbabwe
Harare, Zimbabwe

The Honorable Philip Ndegwa
Governor
Central Bank of Kenya
Nairobi, Kenya

Dr. Collins Ngwa
Senior Lecturer
International Relations Institute of Cameroon
University of Yaounde
Yaounde, Cameroon

Dr. Jesse Theuri Njoka
Senior Lecturer and Chairman
Department of Range Management
University of Nairobi
Nairobi, Kenya

Dr. M. A. Noor
Vice-Minister of Agriculture
Ministry of Agriculture
The Office of the Minister
Mogadishu, Somali Democratic Republic

Dr. Zerubabel M. Nyiira
Research Administrator and
 Principal Research Scientist
The International Centre of
 Insect Physiology and Ecology
Nairobi, Kenya

Professor C.T.I. Odu
Department of Agronomy
Microbiology/Environmental Studies Laboratory
University of Ibadan
Ibadan, Nigeria

Dr. Julius Amioba Okojie
Department of Forest Resource Management
University of Ibadan
Ibadan, Nigeria

Professor R.J. Olembo
Division of Ecosystems and Natural Resources
United National Environment Program
Nairobi, Kenya

Dr. Joe M.A. Opio-Odongo
Department of Agricultural Economics
Makerere University
Kampala, Uganda

Professor C.A. Osuntogun
Faculty of Agriculture
University of Ife
Ile-Ife, Nigeria

Dr. M. Rukuni
Dean
Faculty of Agriculture
University of Zimbabwe
Harare, Zimbabwe

Dr. Abdel Aziz Saad
Plant Protection Director
Ministry of Agriculture and Natural Resources
Plant Protection Directorate
Khartoum North, Sudan

Professeur Abdoulaye Sawadogo
Institute of Tropical Geography
University of Abidjan
Abidjan, Ivory Coast

Dr. John Shao
John Shao Associates
Binghamton, NY

Dr. D.M. Thairu
Dryland Farming Research and Development Project
Machakos, Kenya

Appendix D
External Reviewers

The following people reviewed OTA's draft of *Enhancing Agriculture in Africa: A Role for U.S. Foreign Assistance*. Some people (Part A) reviewed the entire report but were asked to focus particular attention on different sections.[1] Advisory Panelists, listed in the front of this report, also reviewed the entire draft. Others (Part B) reviewed individual sections or chapters. Most of the material regarding animals was added after the first draft was completed so this section's reviewers are listed separately (Part C). Finally, OTA conducted a collaborative review with the U.S. Agency for International Development's Africa Bureau to help AID consider the implications of OTA's work (Part D). The contractor reports on technologies formed the major basis for chapters 7-11. These reports were reviewed separately (app. A).

Part A: Reviewers of Entire Draft Assessment

David Andrews, Department of Agronomy, University of Nebraska, Lincoln, NE (ch. 5)
Joan Atherton, Bureau for Policy Planning and Coordination, U.S. Agency for International Development, Washington, DC (ch. 6)
Coralee Bryant, Overseas Development Council, Washington, DC (ch. 4)
Robert Chambers, Institute for Development Studies, University of Sussex, Falmer, UK (ch. 4)
Beatrice Chileshe, Technology Development and Advisory Unit, University of Zambia, Lusaka, Zambia (ch. 4)
Ralph Cummings, Science and Technology Bureau, Agency for International Development, Washington, DC (ch. 5)
Carl Eicher, Department of Agricultural Economics, Michigan State University, East Lansing, MI (ch. 4)
Milton Esman, Department of Government, Cornell University, Ithaca, NY (ch. 4)
Charles Francis, Department of Agronomy, University of Nebraska, Lincoln, NE (ch. 3)
Peter Freeman, Alexandria, VA (ch. 6)
William Furtick, Science and Technology Bureau, U.S. Agency for International Development, Washington, DC (ch. 5)
Richard Harwood, Winrock International, Morrilton, AR (ch. 5)
Allan Hoben, Director of African Studies, Boston University, Boston, MA (ch. 6)
M.S. Matsebula, Department of Economics, University of Delaware, Newark, DE (ch. 4)
John Mellor, International Food Policy Research Institute, Washington, DC (ch. 4)
Uzo Mukwonye, International Fertilizer Development Center, Muscle Shoals, AL (ch. 3)
David Norse, Agricultural Division, U.N. Food and Agriculture Organization, Rome (ch. 3).
Christine Okali, Oxfam, Boston, MA (ch. 4)
Julius Okojie, University of Georgia, Athens, GA (ch. 4)
Anthony Pritchard, World Bank, Washington, DC (ch. 5)
John Staatz, Department of Agricultural Economics, Michigan State University, East Lansing, MI (ch. 3)
E.T. York, Ormond Beach, FL (ch. 5)

Part B: Reviewers of Specific Chapters

Chapter 4. A Resource-Enhancing Approach to African Agriculture
John Bruce, Land Tenure Center, University of Wisconsin, Madison, WI
Richard Ford, International Development Program, Clark University, Worcester, MA
Thomas Painter, Social Science Research Council, New York, NY
William Rau, Bread for the World, Washington, DC

Chapter 5. The Role of Technology in Enhancing Low-Resource Agriculture
Peter Brumby, World Bank, Washington, DC
Dennis Child, Winrock International, Morrilton, AR
Dana Dalrymple, Science and Technology Bureau, Agency for International Development, Washington, DC

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[1] The draft chapters that reviewers examined and the chapters in this final report do not correspond directly because the text was substantially reorganized and revised following the review. The draft and final material, by reviewer, are matched as closely as possible here.

O.O. Dipeolu, International Center for Tropical Animal Health, Tuskegee University, Tuskegee, AL
Peter Matlon, Food Research Institute, Stanford University, Stanford, CA (also reviewed ch. 3 and ch. 4)
Robert McDowell, Department of Animal Science, North Carolina State University, Raleigh, NC
Michael Sands, Rodale-International, Emmaus, PA

Part C: Material in Chapters 9, 10, and 11 Regarding Animals

Peter Brumby, World Bank, Washington, DC
Dennis Child, Winrock International, Morrilton, AR
O.O. Dipeolu, International Center for Tropical Animal Health, Tuskegee University, Tuskegee, AL
Robert McDowell, Department of Animal Science, North Carolina State University, Raleigh, NC

Part D: Collaborative OTA/AID Review: Chapter 1 Summary and Options and Chapter 6 The Role of Foreign Assistance in a Resource-Enhancing Approach

Bruce Johnston, Food Research Institute, Stanford University, Stanford, CA
William E. Lavery, Office of the President, Virginia Polytechnic Institute, Blacksburg, VA
F.J. Maxwell, Department of Entomology, Texas A & M University, College Station, TX
L.D. Swindale, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh, India
Donald Winkelman, Centro Internacional de Mejoramiento de Maize y Trigo (CIMMYT), Londres, Mexico

Appendix E

The U.S. Department of Argiculture's Database on Low-Resource Agriculture

As part of its determination of the current status of low-resource agriculture, OTA contracted with the Economic Research Service of the U.S. Department of Agriculture to compile data on low-resource production in Africa. An agricultural economist, Dr. John Staatz, and an agronomist, Dr. Charles Francis, then reviewed the data, drew conclusions on low-resource agriculture's current status, and analyzed its potential contributions to food security and economic development.

The U.S. Department of Agriculture (USDA) estimated agricultural production in Sub-Saharan Africa by using a sample of eight countries: Kenya, Malawi, Mali, Nigeria, Senegal, Sudan, Zaire, and Zimbabwe. An agroecological zone map, overlaid on internal regional/political maps of the eight countries, allowed USDA to break down production by agroecological zones.

USDA defined low-resource agriculture as:

> ". . . any agricultural production process in which no modern inputs (e.g. chemical fertilizer, pesticide, hybrid seed) or modern production technology (e.g., tractor, drip irrigation) is utilized (1)."

This definition is considerably narrower than OTA's more qualitative one. Therefore USDA's data are a *lower bound* on the volume or area of various crops produced under low-resource conditions (4). In addition, this definition forced USDA to look at production on a crop basis rather than on any other (how many farmers practice only low-resource agriculture, how many of these farmers are women, etc.). USDA had to use this definition to obtain quantitative estimates of low-resource production because aggregate production data are the only comparable data available across Africa (4).

USDA calculated total crop area and production (within a zone and a country), then subtracted estimates of area and production that were clearly not within this definition. The remaining area and production were considered low-resource agriculture.

Data were collected for 22 agricultural commodities in 4 agroecological zones in the 8 sample countries. These eight countries produce over 50 percent of the maize, sorghum, yams, cocoyams and cotton grown in Africa and 30 percent or more of the rice, wheat, sesame, cassava, and groundnut. Thus, the eight countries' data are a significant indicator for the major food commodities of the region and certain export crops. These data are not a strong indicator for other important export crops, such as the perennial tree crops like coffee and cocoa.

African agricultural data are estimates and significant questions about the quality of this information exist. USDA drew from a number of data sources, including national sources, the U.S. Agency for International Development, the World Bank, and the U.N. Food and Agriculture Organization. OTA assumes that this is the best available data upon which preliminary conclusions can be based (3). Nevertheless, a number of clear data gaps exist. Several important crops (cowpeas, bananas, and plaintains) are not included nor is animal production. Available data did not allow USDA to distinguish between local and improved varieties of perennial crops (e.g., coffee and palm oil). Therefore, the data undoubtedly reflect an overestimate of low-resource production for these crops. Some of the difficulties in gathering this data arise from OTA's desire to base the analysis on agroecological zones. Also, the weakness of the statistical base is a manifestation of the underinvestment in agriculture, and in low-resource agriculture in particular in Africa (4).

Low resource agriculture in Africa, and even within individual African countries, is extremely diverse; hence, any attempt to generalize for the continent as a whole is dangerous. Nonetheless, there are some common features of low-resource agriculture across countries. The USDA data indicate that a very large percentage of major crops in the eight sample countries are grown under low-resource conditions (table E-1). Several patterns emerge:

- Within the arid and semi-arid areas of Africa, most of the basic staples (millet, sorghum, and fonio) are grown under low-resource conditions. If data were available for cowpeas, they probably would show the same pattern.
- A much smaller percentage of maize than millet and sorghum is grown under low-resource conditions in all four ecological zones. This reflects the spread of hybrid maize in east and southern Africa (particularly Kenya and Zimbabwe) and the greater fertilizer responsiveness of maize compared with millet and sorghum, which has encouraged farmers to use chemi-

cal fertilizers on maize. In Kenya, 50 percent of smallholders grow hybrid maize and fertilizer use has reportedly doubled smallholder maize yields (1).

- Most African rice is produced by low-resource agriculture, despite large, capital-intensive irrigation schemes in some semi-arid areas (for example, in Senegal and Mali) where over half the rice is produced under higher-resource conditions. Most of the low-resource rice production is produced under rainfed conditions or in small, low-lying areas using gravity irrigation or seasonal flooding.
- Almost all roots and tubers, which are extremely important staples in the humid areas, are produced under low-resource conditions. This reflects the almost total neglect, until very recently, of attempts to improve these crops by agricultural researchers. With increased population pressure, one would expect a gradual shift toward greater use of these crops because their caloric yield per hectare and per hour of labor is much higher than that of cereals.
- In general, a much higher percentage of export and cash crop production takes place under higher-resource conditions than does food crop production. For example, virtually no cotton, sisal, or pineapples are grown under low-resource conditions and only 32 percent of tea is. About half the production of groundnuts is reportedly produced under low-resource conditions in semi-arid areas, where groundnuts are an important cash crop; in more humid areas, where they are grown for home consumption, the share of low-resource production increases.
- The USDA figures indicate that almost all coffee and palm oil production in the sample countries takes place under low-resource conditions. However, this unexpected result reflects both the sample of countries chosen and difficulties in obtaining data. In most cases, the data did not allow USDA to distinguish between local and improved varieties of these perennial crops. USDA knows, for example, that much of the oil palm production in West Africa, particularly in the Ivory Coast (the leading exporter of palm oil in West Africa but not included in the USDA sample), takes place using improved high-yielding varieties, but precise figures were not available. Or farmers may be using low-resource techniques not because they prefer them or because more productive methods are not known but because the systems for delivering modern inputs have broken down. This apparently is the case for coffee and cotton production in parts of East Africa.

Generally, these findings reflect the greater attention paid to export crops both in terms of agricultural research aimed at producing varieties responsive to manufactured inputs and in terms of developing the supporting institutions (particularly input and output markets) that makes such a reliance on external inputs possible. Although it is commonly asserted that the Green Revolution has bypassed Africa, during the last 60 years agricultural research in Africa has resulted in very significant yield increases for three crops: oil palm, cotton, and maize (in eastern and southern Africa) (2). These achievements are reflected in the low percentage of maize and cotton produced under low-resource conditions.

Production of Basic Food Crops. Total production of food crops and specialty crops is summarized in Table E-2 by crop group and by agroecological zone. Production figures are similar to those for area under cultivation. Cereal grains are the most important crops, and thus the primary sources of energy and protein, in the arid, semi-arid, seasonally humid, and highland regions of Sub-Saharan Africa. Grain legumes contribute substantially to total food crop production, especially in the arid and semi-arid zones, and starchy root crops are important sources of energy in the humid zones—especially the continuously humid zone of the sample countries.

Importance of Low-Resource Food Production. It is clear that low-resource agriculture focuses on production of food crops for local sale and consumption—essentially all of the yams, cocoyams, and cassava are produced this way. In the eight countries, low-resource agriculture also accounted for more than half of the millet, groundnut, and rice produced—recognizing that groundnut is both an export and a subsistence crop.

Specific Crop Results. The USDA data show that levels of productivity under low-resource conditions vary widely with crop and country although comparisons may be questionable due to the quality of the available data (table E-2). Cotton yields under low-resource conditions in the arid and semi-arid zones are about 205 kg/ha, while higher-resource yields in the same zone are calculated to be about 2,276 kg/ha. Thus, yields under low-resource conditions are only 9 percent of those under higher input conditions. Yields of groundnuts across the three lowland zones are about 680 kg/ha under low-resource conditions and 1,180 kg/ha under higher-resource conditions (the former 58 percent of the latter). For sorghum, the respective yields are 635 kg/ha and 827 kg/ha; low-resource productivity is about 77 percent of the yield under improved conditions. Millet, primarily a crop of resource-poor farmers, has yields of 622 and 683 kg/ha under the two conditions and low-resource agriculture yields 91 percent of the higher-resource yields.

Several factors could be responsible for the gaps in yield between low and higher-resource production among these four crops. First, they could reflect the crops' individual importance to governments, to research specialists, and to those who finance research and development. Cotton is primarily a low-value export crop and groundnuts are both an export and a subsistence crop. On the other hand, sorghum is primarily a basic food crop, although areas exist where the crop is grown commercially with added inputs as in the Gezira irrigation project of Sudan. Millet is almost exclusively a subsistence crop, with 70 to 80 percent of the area and production coming from low-resource agriculture. Thus, research on subsistence grain groups may have been less than for export crops and the larger gaps between low- and higher-resource yields may reflect this. Or the yield gaps may exist because of how and where the grain crops are grown—extensively cultivated on more marginal lands. In these areas, production constraints are severe, and responses to technology may be limited by unrelated constraints, for example, plants will not respond to added fertilizer if water is limiting growth.

Conclusion

The primary purpose for gathering and analyzing the USDA data was to determine the relative importance of low-resource agriculture in Africa's current agricultural production. The data show clearly that low-resource agriculture is an important starting point for building food security and economic development of Africa (1,3,4), although different people would come to different conclusions about how this should be done.

In practice, even with its conservative definition of low-resource agriculture, the USDA analysis indicates that low-resource agriculture is extremely widespread in Africa. From the point of view of U.S. foreign assistance policy it probably matters little whether low-resource agriculture accounts for 74 percent or 83 percent of millet production in Africa; what is important is that most producers are low-resource agriculturalists and they account for the bulk of production (4).

Appendix E References

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2. Eicher, Carl, "International Technology Transfer and the African Farmer: Theory and Practice," Department of Land Management, University of Zimbabwe, Working Paper 3/84, May 1984.
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Table E-1.—Production of Various Crops Under Low-Resource Conditions by Agroecological Zone in Eight African Countries[a]

	Agroecological zone				
	Arid, semi-arid	Seasonally humid	Continuously humid	Highlands	Total, all zones[b]
Food crop					
Millet					
Total production[c]	4,289	385	N.A.[d]	240	4,914
% low-resource agriculture	74	67		38	72
Sorghum					
Total production	3,326	2,238	N.A.	N.A.	5,564
% low-resource agriculture	62	59			61
Fonio					
Total production	54	N.A.	N.A.	N.A.	54
% low-resource agriculture	100				100
Maize					
Total production	1,241	3,468	891	1,998	7,598
% low-resource agriculture	35	37	70	23	37
Rice					
Total production	194	956	1,093	39	2,282[e]
% low-resource agriculture	45	67	90	0	75[e]
Beans					
Total production	N.A.	103	68	N.A.	171
% low-resource agriculture		22	90		49
Yams					
Total production	N.A.	4,995	11,655	N.A.	16,650
% low-resource agriculture		100	100		100
Cocoyams					
Total production	N.A.	333	1,332	N.A.	1,665
% low-resource agriculture		100	100		100
Cassava					
Total production	N.A.	6,806	18,435	N.A.	25,241
% low-resource agriculture		92	93		
Export/Cash Crops					
Groundnuts					
Total production	1,882	658	237	N.A.	2,777
% low-resource agriculture	49	60	90		55
Cotton					
Total production	1,835	208	N.A.	12	2,055
% low-resource agriculture	3	3		100	4
Coffee					
Total production	11	7	82	84	184
% low-resource agriculture	0	100	100	100	94
Tea					
Total production	N.A.	N.A.	N.A.	126	126
% low-resource agriculture				32	32
Sisal					
Total production	34	N.A.	N.A.	16	50
% low-resource agriculture	0			0	0
Pineapples					
Total production	N.A.	N.A.	N.A.	155	155
% low-resource agriculture				0	0
Tobacco					
Total production	N.A.	147	N.A.	N.A.	147
% low-resource agriculture		0			0
Wheat					
Total production	235[e]	N.A.	N.A.	222	457[e]
% low-resource agriculture	0[e]			0	0

Table E-1.—Production of Various Crops Under Low-Resource Conditions by Agroecological Zone in Eight African Countries[a]—Continued

	Agroecological zone				
	Arid, semi-arid	Seasonally humid	Continuously humid	Highlands	Total, all zones[b]
Rubber					
Total production	N.A.	N.A.	86	N.A.	86
% low-resource agriculture			58		58
Palm Oil					
Total production	N.A.	22	663	N.A.	685
% low-resource agriculture		99	78		79

[a] Kenya, Malawi, Mali, Nigeria, Senegal, Sudan, Zaire, and Zimbabwe
[b] The percentages shown in this column are weighted averages of the figures for each of the 4 zones.
[c] Data are given in thousands of metric tons
[d] N.A. indicates that no data were available on the production of the crop in the zone. In most cases, this signifies that the crop is not grown in the zone.
[e] Discrepancies between sources corrected by OTA.

SOURCE: Brian D'Silva and Arthur Dommen, "The Role of Low-Resource Agriculture in Africa: Overview and Summary," contractor report to the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987), Table 3; compiled by John M. Staatz, "The Potential of Low-Resource Agriculture in African Development," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987), Table 1.

Table E-2.—Production of Basic Food Crops and Specialty Crops Grown Under "Low Resource" (LRA) Conditions and Total Production of Same Crops

	Cereal grains			Grain legumes			Starchy roots			Specialty crops		
Region	Crop	LRA	Total	Crop	LRA	Total	Crop	LRA	Total	Crop	LRA	Total
Arid, Semi-Arid	Millet	3,189	4,289	Groundnut	920	1,882				Cotton	60	1,835
	Sorghum	2,047	3,326	Soya	0	11				Sisal	0	34
	Wheat	0	235							Coffee	0	11
	Rice	86	194									
	Maize	439	1,241									
	Sesame	72	117									
	Fonio	39	39									
	Total	5,872	9,441		920	1,893		0	0		60	1,880
Seasonally Humid	Maize	1,299	3,468	Groundnut	393	658	Cassava	6,243	6,806	Coffee	6	7
	Rice	636	956	Beans	22	103	Yams	4,995	4,995	Cotton	5	208
	Millet	259	385				Cocoyams	333	333	Tobacco	0	147
	Sorghum	1,314	2,238							Palm oil	22	22
	Sesame	20	20									
	Total	3,528	7,067		415	761		11,571	12,134		33	384
Continuously Humid	Maize	622	891	Groundnut	213	237	Cassava	17,059	18,435	Coffee	82	82
	Rice	984	1,093	Beans	61	68	Yams	11,655	11,655	Rubber	50	86
							Cocoyams	1,332	1,332	Palm oil	516	663
	Total	1,606	1,984		274	305		30,046	31,422		648	831
Highlands	Wheat	0	222							Sisal	0	16
	Rice	0	39							Tea	40	126
	Maize	450	1,998							Coffee	84	84
	Millet	90	240							Cotton	12	12
										Pineapple	0	155
										Sugarcane	1,550	3,107
	Total	540	2,499		0	0		0	0		1,686	3,500
Total (8 country)		11,546	20,991		1,609	2,959		41,617	43,556		2,427	6,595

SOURCE: Charles A. Francis, "OTA Technical Paper Series: Potentials for Development of Low-Resource Technologies for African Agriculture," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987).

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Index

Index

Acacia albida, 10, 85, 171-172, 202, 207
Accelerated Development. *See* Policy reform
Access
  to inputs and information by low-resource agriculturalists, 68, 78, 109, 177-178, 208, 246, 250
  to irrigable land, 185
African Development Bank (AfDB)
  multilateral assistance by, 130-132
  U.S. support for, 31
African Development Foundation, 23, 137
Africa-wide Biological Control Project of Cassava Pests, 260
Agency for International Development, U.S. (AID)
  agroforestry projects supported by, 198, 207, 208
  aquaculture support by, 249
  Congressional oversight of, 132-133
  Development Assistance (DA), 17-18, 31, 126-130
  Economic Support Funds (ESF), 18, 31, 126-130
  fertilizer use policy of, 177
  Food Aid, 31, 128
  fuel efficient charcoal stove development support by, 281
  infrastructural development by, 139
  institution-building support by, 141-143
  livestock emphasis of, 251
  NGOs as intermediaries for, 185
  operational capabilities for resource-enhancing approach to development assistance by, 150-153
  pesticide use guidelines of, 264
  Plan for Supporting Agricultural Research and Faculties of Agriculture in Africa, 19, 25
  policy reform aid by, 146-148
  political influences on, 32, 125, 289
  priorities of, 125
  Regional Food Crop Protection Project (RFCP) of, 263
  resource-enhancing development assistance strategy of, 148-150
  resource-enhancing technologies support by, 169-170
  role of development assistance by, 17, 18, 19, 20, 27-28, 125, 148-150
  Sahel operations, 151
  Small Ruminant Collaborative Research Support Program of, 242
  training support by, 140-141
Agricultural Trade Development and Assistance Act—1984, 291
Agroecological zone
  common intercrops by, 196
  low-resource agriculture by, 50-56
  primary food commodities by, 6, 50-56
  promising technologies and practices by, 15-16, 103, 104
  rice production variation by, 218
  soil fertility maintenance problems by, 177
  USDA data on crops gown by, 313-314, 315
Agroforestry, 114, 208
  benefits and adoption potential of, 204-205
  payback period for, 207
  problems with and approaches to, 205-207
  types of, 200-204
  see also individual technologies using
AIDS, effect on agricultural development of, 37
Alley cropping, 112, 200, 203
  increasing yields by, 172, 176
  livestock integration into, 243, 244, 245
Angola, 9
Animal health. *See* Health, animal
Animal traction, 106, 112, 116, 198, 200, 238, 245-247
Aquaculture, 116
  elements for successful development of, 249
  food security using, 241, 242
  opportunities for improved use of, 248-250
  potential drawbacks to using, 248-249
Asia
  fertilizer credit use in, 178
  integrated crop/livestock production in, 242
  integrated fish/livestock/crop production in, 248
  large-scale irrigation in, 184
  "night soil" use in, 173
  striga problem in, 221
Azolla-Anabaena, 171, 172, 175

Benin
  chorkor oven use in, 280
  crop breeding and productivity in, 219
Bilateral assistance, U.S., to Africa, 31-32, 126-130
Biological nitrogen fixation (BNF), 10, 85, 171-172, 175, 177, 202, 207
Biotechnology, impact on African agriculture of, 221, 222
Botswana
  animal traction use in, 245
  water management in, 164

Brazil
  as competitor to U.S. global agricultural trade, 289, 290
  IPM use in, 262
Breeding, animal and plant
  cautions concerning crop, 220-221
  choosing appropriate priorities when, 222-224
  improvements in techniques for, 115-116
  non-technological problems with crop, 221-226
  pest resistance into African plants and livestock, 259
  potential of individual African crops, 215-220
  potential of specific African animals, 227-231
  terminology, 213
Bunds, 163-164
Burkina Energy Institute, 281
Burkina Faso, 9
  fertilizer use in, 175, 177
  fuelwood shortages in, 64
  health care training in, 107
  water management in, 162, 163-164, 168, 182
Burundi
  crop breeding and productivity in, 216, 219
  population density in, 61

Camels. *See* Livestock
Cameroon, 263
  animal confinement use in, 268
  crop breeding and productivity in, 219
  effectiveness of plant protection in, 262
  small-scale fishery promotion in, 241
Canadian International Development Research Center (IDRC), 267
Cape Verde, water management in, 162, 168
CARE, agroforestry projects by, 203-204, 205
Cassava, 9
  breeding, 219, 220
  processing, 277
  storage, 275
  USDA data on, 311
Cattle. *See* Livestock
Central African Republic, 261
Chad
  hydrological research in, 186
  small-scale, irrigation use in, 181, 182
China, 172
CILSS, Integrated Pest Management Project of, 263
Club du Sahel, irrigation use research by, 186
Colorado State University, 292
Community Forestry Project (Guinea)—AID, 207
Congress, U.S., 3, 17, 18, 20
  direction and priorities for development assistance by, 124-125
  findings and options on African development assistance for, 21-32, 105-110
  funding a resource-enhancing approach to development assistance by, 125-132
  oversight of a resource-enhancing approach to development assistance by, 132-134
Congressional Research Service (CRS), computerizing foreign assistance budget of, 132-133
Conservation tillage, 167-168
Constraints
  on African farmers' investment in improvements, 49-50, 116, 169-170, 182-183, 206-207
  to agroforestry adoption, 206-207
  on AID operational capabilities, 151-152
  biophysical and socio-economic on agricultural productivity, 64-66, 173, 175, 177-178, 185, 198-199, 266-269
  to crop breeding success, 216
Consultative Group on International Agricultural Research (CGIAR)
  breeding effects evaluation by, 221
  IARC support by, 144-146
  U.S. contribution to, 130
Contour planting, 163
Costa Rica, 244
Costs. *See* Expenditures; Funding
Crops
  by agroecological zone, 50-56
  breeding for improved, 215-226
  drying and storage methods for, 274-275
  effectiveness of protection programs for, 261-262
  germplasm conservation of, 220-221
  intensive feed garden approach to growing, 243, 244, 245
  limiting pest damage to, 257-264
  processing methods for, 273-278, 279
  production estimates for low-resource agriculture, 57-58, 62, 100
  USDA data on low-resource production of, 310-312, 313-314, 315

Data collection
  agricultural reform policy, 148
  AID-wide system for, 152
  on livestock breeding, 227
  on quarantine cost-effectiveness, 259
  USDA low-resource agriculture, 59, 310-312
  on women's activities, 148
Debt, external, 36
Deforestation. *See* Degradation

Degradation, of natural resource base, 63, 64, 77-78, 80, 81, 198, 200, 201, 207
Department of Agriculture, U.S. (USDA)
  database on low-resource agriculture of, 310-312
  Soil Classification System of, 170
Department of State, U.S., 22, 32
  AID's dependence on, 125, 289
Department of Treasury, U.S., 23, 24, 26
Desertification. *See* Degradation
Development assistance, 77-78
  African perspectives on priorities for, 92-94
  AID's responsibility in a resource-enhancing approach to, 148-153
  assessment of approaches to, 88-92
  benefits to U.S. farm sector from U.S., 291-292
  categories of a resource-enhancing approach to, 134-148
  concepts central to a resource-enhancing approach to, 78-88
  conflicting U.S. interests impact on African, 287-289
  Congress and a resource-enhancing approach to, 124-134
  difficulty in assisting pastoralists with, 237, 239, 240
  effects of support for African, on U.S. agriculture, 289-292
  farm interest groups-backed restrictions on, 289-291
  findings and options for Congress concerning, 21-32
  main goal of, 292
  see also Bilateral assistance; Congress, U.S.; Multilateral assistance; individual donor organizations
Development Fund for Africa, FY 1988, 18, 31
Diversity
  African cultural and ecological, 3, 45, 46-50
  as component of low-resource agriculture systems, 59, 81-84, 106-107
  development assistance priorities to promote, 81-84
  in technologies for Africa, 106-107
Drainage practices, 165-166
Du Pont, 183

Education. *See* Training
Efficiency, of low-resource agriculture and pastoral systems, 50, 77, 78, 84-86, 237
Employment
  low-resource agriculture as primary, 3, 45, 58-59, 77, 78
  non-farm, 110
  see also Labor
Equity
  biotechnology in plant breeding and, 221, 222
  in development assistance, 90-91
  livestock ownership and social, 238
Ethiopia
  agroforestry in, 205
  animal traction use in, 245
  cheesemaking in, 278
  crop breeding and productivity in, 216
  famine threat to, 287
  hand pump use in, 183
  livestock breeding and productivity in, 227
  refugees from, 208
European Economic Community (EEC), 177
Expenditures
  on biological pest control, 260
  government agricultural research, 66, 68, 69, 224, 225
  on irrigation projects in Africa, 183, 186
  see also Funding
Extension services, underdevelopment of African, 68-69, 186-187

Famine
  buffers against, 59-60
  U.S.-funded relief for, 78, 125, 135
Farming systems research (FSR), 108, 186, 221, 292
Federal Livestock Department (Nigeria), 244
Fertility. *See* Soil
Fertilizer
  inorganic, 174-175, 175-177
  long-term effects of commercial inorganic, 176-177
  organic, 171-174, 175, 177
  supply and demand problems involving, 177-178
  use in aquaculture of, 248
Findings and options for Congress concerning development assistance to low-resource agriculturalists, 21-32, 105-110
Fisheries
  development of African low-resource, 237, 241
  processing catch of, 278
Fodder banks, 244
Food and Agricultural Organization, U.N. (FAO), 16
  chorkor oven development assistance by, 280
  cropland condition estimates by, 114, 115
  fertilizer use policy of, 177
  Fishery Committee for the Eastern Central Atlantic of, 241

  irrigation estimates by, 184, 186
  management practices demonstrations by, 113
  natural resource degradation estimate by, 63
  pesticide use guidelines of, 264
  quarantine study by, 259
  trypanosomiasis infected area estimates by, 265
  U.S. contribution to, 130
  yield increases estimates by, 65
Food Research Institute (Ghana), 280
Food security
  contribution of low-resource agriculture to, 21, 56-60, 77-78
  definition of, 3
  demand side of, 35-36
  need to improve African, 35, 38, 224
  obstacles to achieving, 64-69, 100-103
  as overarching goal of AID-provided development assistance, 125
  technologies for improving African, 111-117
  U.S. economic interests in promoting African, 288
Foreign Assistance Act—1961, 88, 89, 124-125, 135
Francis, Charles, 310
Fuelwood
  collection and deforestation, 64, 207-208
  increase in, from using agroforestry techniques, 204
  use for food processing, 279
Funding
  crop research and food security, 224
  U.S. bilateral, 126-130, 148-149
  U.S. multilateral, 130-132
  see also Expenditures

Gabon, crop breeding and productivity in, 219
Gardens, home, 56, 81, 82, 104, 243-245, 248
Genetic improvements. *See* Biotechnology; Breeding
German Appropriate Technology Exchange (GATE), 278
Ghana
  crop breeding and productivity in, 219
  pesticide use subsidies in, 264
  small-scale irrigation use in, 182
  women in fisheries of, 241
Goats. *See* Livestock; Small ruminants
Gravity diversion irrigation systems (channeled and poldered), 180-181
Green Revolution
  applicability to Africa of, 100-102, 311
  social effects of, 221
  technology packages for Africa, 214-215
Grey, David, 183
Gross domestic product (GDP), agriculture's contribution to African, 3, 45-46
GTZ (West Germany), 177
Guidelines
  to determine appropriate technology choices, 179, 257-258, 264
  researcher/agriculturalist cooperation, 109
  to support a resource-enhancing approach of development assistance, 79, 81, 84, 86
Guinea
  agroforestry use in, 204, 207
  chorkor oven use in, 280
  crop breeding and productivity in, 216
  effectiveness of plant protection in, 261
Guinea-Bissau, 180, 181, 263, 280

Health
  impacts of aquaculture on, 248-249
  intercropping impacts on crop, 198, 199
  pesticides impact on human, 261
Health, animal, 226, 228-229, 230, 245, 264-273

Incentives
  encouraging conservation measures, 165
  from governments to increase food production, 221
  for pesticide use, 264
Income
  African per capita, 62
  from fisheries in Africa, 237
  from livestock in Africa, 237, 240
  low-resource agriculture as source of, 58-59
India
  handpump use in, 183
  improved crop use in, 216
  non-resistant sorghum from, 221
Infrastructure
  controversy over developing rural, 139
  improving, for IPM implementation, 262, 263
  weaknesses in agricultural, 67-68, 177-178, 215, 225, 261
Inputs. *See* individual inputs
Insects. *See* Health; Integrated Pest Management; Pests
Integrated Pest Management (IPM), 117
  challenges facing African implementation of, 262-264
  components of successful program using, 258-261
  criteria for choosing optimal methods of, 257-258

  information as primary input in programs of, 261-262
  potential for effective use of, 261-263
Intercropping, 195-200, 201-203
International Agricultural Research Centers (IARCs), 14, 26, 144, 146
  impact of U.S. research ban on, 291
  intercrop research by, 109
  IPM expertise of, 263
International Bank for Reconstruction and Development (IBRD)—World Bank, 131
International Center for Genetic Engineering and Biotechnology, 222
International Center for Insect Physiology and Ecology (ICIPE)—Kenya, 144
International Council for Research on Agroforestry (ICRAF)—Kenya, 144
International Fertilizer Development Center (IFDC)—U.S., 144, 178
International Food Policy Research Institute (IFPRI) approach, 12, 88, 90, 91, 92
International Fund for Agricultural Development (IFAD), 130
International Institute of Tropical Agriculture (IITA)—Nigeria, 144
  Africa-wide Biological Control Project of Cassava Pests, 260
  crop/livestock integration research by, 243, 244
  crop research by, 68, 203
  hybrid crop varieties developed by, 217, 218, 219
  water management research by, 164
International Laboratory for Research on Animal Diseases (ILRAD)—Kenya, 144
International Livestock Centre for Africa (ILCA)—Ethiopia, 144
  alley cropping farm trials by, 203
  animal traction technology improvements by, 247
  crop/livestock integration research by, 243, 244
  dairy technology developed by, 278
  Humid Zone Programme of, 244
  research in small ruminants by, 228
  staffing bias of, 266
  Subhumid Zone Programme of, 244
International Potato Institute (CIP)—Peru, 222
International Service for National Agricultural Research (ISNAR), 146
International Soybean Program (U.S.), 144
Irrigation
  factors favoring expansion of low-resource, 185
  gravity diversion systems for 180-181
  small-scale technology for, 115
  water-lifting and pumping systems for, 181-184
Ivory Coast
  animal traction and transport equipment factories in, 247
  crop breeding and productivity in, 219
  effectiveness of plant protection in, 262
  palm oil production in, 311

Kenya
  AID livestock programs in, 152-153
  improved shellers use in, 274, 277
  animal confinement use in, 268
  crop breeding and productivity in, 216, 217, 222
  cultural crop control use in, 259-260
  dual-purpose goat production in, 245
  effectiveness of plant protection in, 262
  fertilizer use in, 172, 176
  fuel-efficient stove developed in, 281
  handpump use in 183
  inoculated legumes use in, 172
  livestock breeding and productivity in 229
  pesticide production in, 260
  population and farm size in, 61
  technology acceptance in, 105
  USDA data on, 310, 311
  water management in, 162, 166-167, 180
Kenya Cooperative Creameries, 227
Kenya Industrial Research and Development Institute (KIRDI), 276
Kenya Water for Health Organization, 183
Kenyan National Council of Women, 279
Koro Village Agroforestry Project (Mali)—CARE, 209

Labor
  dependence on household, 49-50, 78, 81-84, 110, 185, 221
  intercropping impacts on, 198
Land tenure
  agroforestry use and, 206-207
  livestock ownership trends and, 239, 240
Legumes
  food, 218, 277, 311
  inoculated, 172
  use in dual-purpose systems of, 244, 245
  see also Acacia albida; Biological nitrogen fixation
Leucaena leucocephala, 176
Linear plantings. *See* Live fencing

Linkages
  among researchers/extension agents/agriculturalists, 107
  development assistance's support for agricultural/non-agricultural, 86-88
Live fencing, 200, 204
Livestock
  breeding for improved, 226-231
  contribution to agricultural development of, 237, 238
  control methods for major diseases affecting, 245, 267
  distribution (by farming system), 237, 238
  fertilizer from, 173
  imbalances in technical support health services for, 272
  improving animal nutrition for, 266-269
  improving veterinary support for, 265-266
  integrating into cropping systems of, 116, 205-206, 241
  improved use of, 243-247, 250-252
  mechanisms to improve health of, 264
  promotion of an integrated development approach for, 270-272
see also Animal traction, Health, animal: Small ruminants
Low-input agriculture, FAO definition of, 48
Low-resource agriculture, definition and characterization of, 3, 4, 5, 46-47, 310

Madagascar
  crop breeding and productivity in 218
  small-scale irrigation use in, 180
Maize
  breeding, 217-218
  processing, 276
  USDA data on, 310, 311, 312
Majjia Valley Windbreak Project (Niger), 203, 204, 206
Malawi, 4, 51
  crop breeding and productivity in, 216
  handpump use in, 183
  livestock breeding and productivity in, 227
  maize production in, 105-106
  USDA data on, 310
  water management in, 164
Malaysia, 289
Mali, 4
  agroforestry projects in, 207
  animal traction and transport equipment factories in, 247
  animal traction promotion in, 252
  crop breeding, and productivity in, 175, 217, 251
  nomadic herding in, 52
  Peace Corps operations in, 137
  policy reform problems in, 147
  privatization of low-resource systems in, 187
  small-scale irrigation use in, 182
  USDA data on, 310, 311
Malnutrition
  increase in, 62-63
  as major constraint on livestock productivity, 266
Manuring, 114, 115, 173-174, 175, 176
Mauritania
  fuelwood shortages in, 64
  small-scale fishery promotion in, 241
  small-scale irrigation use in, 182
McPherson, M. Peter, 152
Michigan State University, 21
Microcatchments, water harvesting, 162-163
Military assistance, developmental impact of, 126, 289
Millet
  breeding, 215-216
  drought resistance of, 196
  USDA data on, 310, 311, 312
Minimum tillage, 114, 115, 167-168
Mixed crop/livestock systems, 116, 205, 206, 241
Morehead State University (Kentucky), 292
Mulching, 114, 115, 167-168
Multilateral assistance, U.S., to Africa, 31-32, 130-132
Multilateral development banks (MDBs). *See* individual bank names

National Council for Science and Technology (Kenya), 275
National Plant Quarantine Station (Kenya), 222
National Range Agency (NRA), 207-208
Natural resources. *See* Resources
New Directions/basic human needs approach, 88-89, 124-125
Niger, 10
  agroforestry use in, 200
  crop breeding and productivity, in 217
  fertilizer use in, 176
  Peace Corps operations in, 137
  phosphorus deficiency in soil of, 175
  privatization of low-resource systems in, 187
  resource degradation in, 80
  water management in, 162
  windbreak projects in, 203-204
Nigeria
  biological pest control use in, 260, 262
  crop breeding and productivity in, 217, 219
  effectiveness of plant protection in, 262

  fertilizer consumption in, 175
  food security study in, 61
  hydrological research in, 186
  intercropping use in, 196, 197, 198
  on-farm investigations of alley cropping in, 243, 244
  pesticide use in, 260
  pest resistant cassava clones use in, 259
  USDA data on, 310
Nigerian Institute of Agriculture, 69
Night soil, 173
Non-governmental organizations (NGOs). *See* Private sector; Private voluntary organizations (PVOs); individual organizations

Office of Overseas Scientific and Technical Research (ORSTOM)—France, 186
Overseas Education Fund (OEF), 208
Oversight, 28-30
  coordinating and improving congressional, 132-133
  reducing the burden of congressional, 133-134
Oxfam, 163, 249

Pakistan, cattle imported from, 227
Pan-African Forum of African Voluntary Development Organizations (FAVDO), 138
Parc National des Volcans (Rwanda), 169
Pastoralists
  categories of and strategies used by, 237, 239, 240
  efficiency of low-resource systems used by, 50, 77, 78, 84-86, 237
  linkages with farmers by, 53
  profile of, 4, 52
Peace Corps
  African development assistance by, 18, 23, 26, 27, 28, 136-137
  Fish Culture Expansion Project of, 249-250
  water harvesting microcatchments introduction by, 162-163
Personnel
  AID training of, 140-141
  CGIAR training of African, 145-146
  lack of qualified quarantine, 259
  need for trained fertilizer use, 177, 178
  shortages in extension service, 68-69
Peste de Petit Ruminant (PPR), 245
Pesticides, 260-261
  environmental impact from use of, 261
  improved use of chemical, 263-264
Pests
  biological controls for, 260
  breeding resistance to, 259
  cultural controls for, 259-260
  options for managing, 258-261
  resistance to pesticides developed by, 261
Plantains, 219-220
Policy
  African development assistance and U.S. foreign, 287-289
  chemical pesticide trade, 261, 263-264
  comparative assessment of types of development assistance, 88-92
  national breeding, 226
  national crop pricing, 66-67
  objectives of the United States, in Africa, 288-289
  reform, 12, 66-67, 88, 89-90, 146-148, 187
  unsupportive national and donor, 66-67, 87-88, 146-148, 187, 221
Population
  challenge of growing African, 60-61, 100
  urban migration of African, 110
Private sector
  African rural non-farm, 138-140
  role in diffusion of low-resource irrigation technologies of, 185
  seed laws and investment by, 225
Private and voluntary organizations, U.S. (PVOs)
  African development assistance by, 26, 27, 28, 134-136
  agroforestry projects by, 205
  local level work by, 137-140
  water harvesting microcatchments introduction by, 162-163
  windbreak projects supported by, 203-204
  see also Private sector; individual organizations
Public opinion, on foreign assistance, 20, 287, 288, 292-293

Quarantines, 258-259

Recession farming, 162
Regional Food Crop Protection Project (RFCP), 263
Research
  coordination of, 144, 272-273
  on crop/livestock integration, 243-245, 250-251, 252

on factors determining technology adoption, 170
Farming systems (FSR), 108, 186, 221, 292
farm interest groups-backed restrictions on U.S. aid for, 20, 290-291
government expenditures for, 68, 69, 224, 225
increasing African capacity for, 24-25, 107
increasing cooperation in health-related, 272-273
legume, 218
level of support for agricultural (by region), 69
livestock management, 226, 228, 229, 230, 231, 243, 250, 252
misguided policies for, 67, 176, 290-291
needs for intercropping, 198-200
on-farm adaptive, 107, 176, 221-222

Resources
- continuum in use of, 47-48
- deterioration in base of, 63-64, 77-78, 100, 198, 240, 241
- development assistance donor's reliance on external, 110
- development assistance use of untapped local, 21, 84-86
- technology potential based on improved use of natural, 113-114
- yield increases through efficient use of natural, 197-198

Reuter News Agency, 260

Rice
- breeding, 218
- processing, 276-277
- USDA data on, 310, 311

Roots and tubers
- breeding, 219, 220
- USDA data on, 311

Ruminants. *See* Livestock; Small ruminants

Rwanda
- animal confinement in, 268
- crop breeding and productivity in, 216, 219
- fertilizer use in, 172, 173, 177
- inoculated legumes use in, 172
- population density in, 61
- water management in, 169

Seed
- improving multiplication and distribution of improved, 224-226
- support for locally managed nurseries to supply, 207

Semi-Arid Food Grains Research and Development (SAFGRAD), 164

Senegal, 10
- animal traction and transport equipment factories in, 247
- crop breeding and productivity in, 216
- pesticide use in, 261, 264
- phosphorus deficiency in soil of, 175
- small-scale fishery promotion in, 241
- small-scale irrigation use in, 182
- USDA data on, 310, 311

Sheep. *See* Livestock; Small ruminants

Shelterbelts. *See* Windbreaks

Sierra Leone, fisheries economics study in, 241

Small holding/small farm, 48

Small Ruminant and Camel Group, 228

Small Ruminant Collaborative Research Support Program (SR-CRSP)—Kenya, 228, 242

Small ruminants, 4, 228-229, 243-245

Soil, fertility-enhancing technologies, 114-115, 170-178

Somalia
- community agroforestry in, 207-208
- effectiveness of plant protection in, 261
- small-scale irrigation use in, 180

Somalia Community Forestry Project, 207-208

Somali Women's Democratic Organization (SWDO), 207-208

Sorghum, 108, 196
- breeding, 216-217
- processing, 275-276
- USDA data on, 310, 312

South America, cassava mealybug introduction from, 258

Southern African Development Coordination Committee (SADCC), 31, 126-129

Special Program for African Agricultural Research (SPAAR), 144

Spoilage, technologies to decrease post-harvest crop loss from, 273-281

Staatz, John, 310

Strong, Maurice, 287

Subsistence farm, 47, 48

Sudan, 10
- agroforestry in, 205
- crop breeding and productivity in, 216, 217, 224, 225
- intercropping use in, 198
- privatization of low-resource systems in, 187
- small-scale irrigation use in, 182
- USDA data on, 310, 312

Sustainability
- of agricultural production, 78, 207
- concept of, 10-11, 16, 78-80
- development assistance priorities to develop and maintain, 79-81, 152-153

- incorporating, into animal disease eradication programs, 270
- of intensive feed garden system, 243-245
- of IPM approaches, 258
- signs of declining, 63-64, 77-78, 80, 198, 200, 201, 207

Swine. *See* Livestock

Systems
- approach to agricultural development, 11-12, 86-88, 105-106
- characteristics of low-resource agricultural, 48-50, 77-78
- concepts central to a resource-enhancing role of development assistance for low-resource agricultural, 79, 81, 84, 86
- efficiency of low-resource agricultural, 237
- improving links between agricultural and external, 86-88
- integrated fish/livestock/crop, 248-249
- land classification, 170
- livestock/crop production, 116, 241-245

Tanzania
- animal confinement in, 268
- aquaculture projects in, 244
- changing farming systems in, 87
- crop breeding and productivity in, 216, 217
- handpump use in, 183
- small-scale irrigation use in, 180
- water management in, 164, 168

Technologies, 13-17
- evaluating potential of, 111-117
- as a factor in improving low-resource agriculture, 100-103, 246-247, 273-281
- Green Revolution, 214-215
- improving agriculturalists acceptance of, 105-110
- promising, 14-17, 103-105
- sequential changes in, 112
- transfer to low-resource agriculturalists of, 106, 107, 111-117
- *see also* individual technologies

Terracing, 114, 166-167

Tied Ridges, 164

Togo
- chorkor oven use in, 280
- crop breeding and productivity in, 219
- small-scale irrigation use in, 182
- women in fisheries of, 241

Trade
- African agricultural export, 36, 45, 58-59
- in chemical pesticides, 261, 263-264
- effects of support to African agriculture on U.S., 289-291

Training
- in agroforestry techniques, 208
- increasing African, 24-25, 92, 107, 140-141, 186-187, 206, 208
- AID support for African agricultural institution personnel, 140-141
- CGIAR-provided personnel, 145-146
- lack of low-resource irrigation skills, 186-187
- pyramid system for, 107

Tropical Development and Research Institute (TDRI), 274, 276

Trypanosomiasis, 5, 6, 226, 265, 267, 270

Uganda, crop breeding and productivity in, 216, 219

United Nations, 31, 61

United Nations Children's Fund (UNICEF), 130
- chorkor oven development assistance by, 280
- handpump use support by, 183
- improved shell removers developed by, 274, 277

United Nations Development Fund for Women (UNIFEM), policy reform assistance by, 148

United Nations Development Program (UNDP), 130, 183

United Nations Food and Agriculture Organization. *See* Food and Agriculture Organization, U.N. (FAO)

U.S. Coastal and Geodetic Survey, 186

Vesicular-arbuscular mycorrhizae (VAM), 172-173

Vietnam, 172

Water-lifting and mechanized pumping irrigation systems, 181-184

Water use, technologies which improve, 115, 162-170, 180-185

West African Rice Development Association (WARDA)—Liberia, 144, 172

Windbreaks, 200, 203-204

Women
- extension service and credit discrimination against, 68, 84, 110, 185
- fish smoking technology invention by, 280
- role of, in African agriculture, 49, 56, 81-84, 106, 185, 207-208, 221, 241

World Bank
- African population projections by, 61
- congressional influence on, 134
- handpumps project of, 183

  institution-building support by, 142
  multilateral assistance by, 18, 19, 20, 23, 24, 25, 26, 28, 31, 130-132
  pesticide use guidelines of, 264
  policy reform aid by, 22, 146, 147, 148
World Health Organization (WHO), AIDS statistics by, 37

Yields
  Acacia albida effect on, 10, 85, 171-172, 202, 207
  fallow periods and crop, 61, 100
  gaps in (from experiment station to on-farm), 111, 221-222
  grain, by region (worldwide), 214
  intercropping benefits to, 197-198
  obstacles to improving crop, 64-69, 105-106, 109
  optimizing stable, 81-84
  USDA data on crop, 311-312, 313-314, 315

Zaire
  AIDS care in, 37
  aquaculture projects in, 244-250
  crop breeding and productivity in, 216
  intercropping use in, 196, 197, 198
  Peace Corps operations in, 137
  USDA data on, 310
Zambia
  crop breeding and productivity in, 216, 217
  fertilizer use in, 172, 175
  inoculated legumes use in, 172
Zimbabwe
  crop breeding and productivity in, 216, 217
  fertilizer use in, 172, 175
  inoculated legumes use in, 172
  incentives for technology acceptance in, 105
  USDA data on, 310

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